Great Lakes Diversions and Consumptive Uses

Report to the International Joint Commission

by the
International Great Lakes Diversions and Consumptive Uses Study Board
(Under the Reference of February 21, 1977)

September 1981

CONVERSION FACTORS

(ENGLISH TO METRIC UNITS)

1 cubic foot per second (cfs) = 0.028317 cubic metres per second (cms)

1 cfs-month = 0.028317 cms-month

1 foot = 0.30480 metres

1 inch = 2.54 centimetres

1 mile (statute) = 1.6093 kilometres

1 ton (short) = 907.18 kilograms

1 ton (long) = 1016.40 kilograms

1 square mile = 2.5900 square kilometres

1 acre - foot = 1233.5 cubic metres

1 gallon (U.S.) = 3.7853 litres

1 gallon (Imperial) = 4.5459 litres

1 acre = 4047 square metres

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INTERNATIONAL GREAT LAKES DIVERSIONS AND CONSUMPTIVE USES STUDY BOARD
Ottawa, Ontario
Chicago, Illinois

September 1, 1981

International Joint Commission
Ottawa, Ontario and
Washington, D.C.

Gentlemen:

The International Great Lakes Diversions and Consumptive Uses Study Board is pleased to submit herewith its report on the study of diversions and consumptive uses associated with the Great Lakes basin. The Study Board was established in May 1977 subsequent to a reference from the Governments of the United States and Canada to the International Joint Commission, dated 21 February 1977.

The findings and conclusions reached by the Board as well as its recommendations are contained in Section 9 and the Executive Summary. Details of the studies and investigations carried out by the Board are contained in three appendices (bound in separate volumes) and seven annexes to the main report (Annex F - Consumptive Water Use and Annex G - Evaluation of Diversion Management Scenarios and Consumptive Water Use Projections, bound separately).

The Board wishes to acknowledge with thanks the assistance and guidance provided by the Commission and numerous other public and private agencies during the course of the study.

Respectfully submitted,

Members for United States

BG S.B. Smith

J.D. Hebson

R.T. Weston

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R.H. Smith

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D.N. Jeffs

EXECUTIVE SUMMARY

Introduction

By a Reference from the Governments of the United States and Canada, dated February 21, 1977, the International Joint Commission (IJC) was "requested to examine into and report upon the following matters which have, or may have, material effects on water levels and flows of the Basin, including the international and Canadian reaches of the St. Lawrence River:

1. Existing and reasonably foreseeable patterns of consumptive uses of Great Lakes waters;

2. Existing diversions, including the Welland Canal and the New York State Barge Canal, and federal, state or provincially sponsored or approved proposed new or changed diversions, within, into or out of the Basin, and, in particular,

3. Existing diversions at Chicago and at Long Lac/Ogoki, and the proposed study and demonstration program authorized by United States P.L. 94-587 affecting the rate of diversion at Chicago.".

In response, the Commission established the International Great Lakes Diversions and Consumptive Uses Study Board on May 3, 1977, issued a Directive to it concerning the conduct of the study, and subsequently instructed it to consider the possibilities of diversion management to alleviate extreme lake levels. The Board, in turn, established a Working Committee and three Subcommittees: Diversions, Consumptive Uses, and Environmental Evaluation. In view of the fact that several basic elements of the study (notably evaluation of the economic effects of various projected hydraulic regimes on the Great Lakes) were the same as those involved in an investigation which was concurrently conducted by the International Lake Erie Regulation Study Board, the technical subcommittees of this latter Board carried out many of the computations on behalf of the Diversions and Consumptive Uses Board. This cooperation maximized the use of available professional resources, avoided duplication of effort and ensured comparability of data and results. In this report of the Diversions and Consumptive Uses Study, therefore, evaluation methodologies are only briefly discussed; more detailed information is given in the Lake Erie Board's report.

During the course of the study, the Board published a series of newsletters designed to keep the public informed of its progress. In 1980, the Board conducted public workshops at selected cities in the Great Lakes basin. These workshops provided further opportunities to inform the public and, through open discussion, to answer questions and elicit views concerning study techniques and emerging results. These views have been incorporated in the Board's work.

Definitions

As indicated by the Reference, the Study has two distinct components: diversions and consumptive uses. Both are factors which affect Great Lakes levels and flows. The Commission's 1976 report to the governments on "Further Regulation of the Great Lakes" discusses all natural and artificial factors affecting the hydrology and hydraulics of the system, but includes a recommendation to the governments that these two factors require a more thorough examination. In this study, a diversion is defined as a transfer of water either into the Great Lakes watershed from an adjacent watershed, or vice versa, or from the watershed of one of the Great Lakes into that of another. All existing diversions are by means of channels controlled by man-made structures. Consumptive use is defined as that portion of water withdrawn or withheld from the Great Lakes and assumed to be lost or otherwise not returned to them due to evaporation during use, leakage, incorporation into manufactured products, etc.

Study Findings

The study findings are as follows:

"a. The existing diversions have produced changes in Great Lakes levels and outflows;

b. Diversion rates could be modified without structural change at existing diversion locations;

c. By management of the diversions it is possible to impact on the Great Lakes outflows and extreme high lake levels, but such management would result in a net economic loss and some unquantifiable environmental impacts;

d. Any alterations in diversion rates to raise the extreme low lake levels and outflows would be infeasible;

e. The existing diversion of water through the New York State Barge Canal has no material impact on Great Lakes levels, nor would any modifications thereof;

f. Diversion of water into Lake Superior from Long Lac/Ogoki has averaged 5,600 cfs since its inception;

g. The Welland Canal Diversion has varied over time and averaged approximately 9,200 cfs in 1980;

h. The Lake Michigan Diversion at Chicago has varied over time and since 1970 has averaged 3,200 cfs;

i. There are no known significant new or changed diversions proposed for the Great Lakes;

j. Consumptive uses of water are projected to increase from the 1975 rate of 4,900 cfs to an amount which could range from approximately 16,000 cfs to 37,000 cfs by the year 2035;

k. The consumptive uses of water reduce the net water supply to the lakes, thereby lowering lake levels, resulting in economic benefits to coastal zone interests and losses to navigation and power interests; and,

l. Consumptive uses in the future will limit the ability of the current operational regulation plan for Lake Ontario to satisfy the criteria contained in the Commission's Orders of Approval.".

Board's Conclusions

The Board's conclusions are that:

"a. The diversion rates into, within and out of the basin cannot be altered to reduce extreme high levels on the Great Lakes without causing an overall long-term net economic loss;

b. The diversion rates into, within and out of the basin cannot feasibly be altered to increase extreme low levels on the Great Lakes during periods of low supplies;

c. Periodically, all diversions regardless of size should be monitored and their accumulated effects estimated, evaluated and reported upon so that appropriate public policies can be developed; and,

d. Consumptive uses should be periodically monitored and their impacts, along with various control strategies, studied so that appropriate public policies can be developed to minimize long-term adverse effects.".

Board's Recommendations

The Board recommends that:

"a. No further consideration be given to the concept of managing Great Lakes levels and outflows through the manipulation of the existing diversions; and,

b. The International Joint Commission, in light of conclusions (c) and (d) above, recommend to Governments that a mechanism be established for institutional consultation so that monitoring can be undertaken and appropriate public policies can be formulated to address the potential future impacts of new or increased diversions and consumptive uses.".

The Great Lakes System

The study area encompasses the Great Lakes-St. Lawrence River system from the westerly end of Lake Superior to Trois-Rivières on the

St. Lawrence River, about 80 miles downstream of Montreal. This system is bordered by eight states - Minnesota, Wisconsin, Illinois, Indiana, Michigan, Ohio, Pennsylvania and New York - and by the provinces of Ontario and Quebec. The total water surface area of the Great Lakes and their connecting channels is about 95,000 square miles. A map of the area is shown in Figure 1 and a hydraulic profile is shown in Figure 2.

Lake Superior, the uppermost and largest of the Great Lakes, discharges through the St. Marys River into Lake Huron. The outflow, through navigation, hydro-power and other facilities in the St. Marys Rapids area, is controlled by the International Lake Superior Board of Control, under the supervision of the IJC, in accordance with Regulation Plan 1977. Lakes Michigan and Huron are connected by the broad and deep Straits of Mackinac. For this reason, they stand at virtually the same level and are usually treated as one lake in hydraulic and hydrologic considerations. Lake Huron discharges through the St. Clair River, Lake St. Clair and the Detroit River into Lake Erie. This flow is unregulated and is governed by the levels of both Lake Huron and Lake Erie.

The natural outlet of Lake Erie is the Niagara River, the total flow through which is also unregulated. However, there is a control structure in the river immediately upstream of Niagara Falls which assists in the apportionment of the flow between the water available for power generating stations and water which is required to pass over the falls in accordance with the Niagara River Treaty of 1950. This structure cannot control the outflow from Lake Erie and therefore cannot be used to regulate Lake Erie levels. The outflow from Lake Erie passes into Lake Ontario, the lowest in the chain of Great Lakes. Due to the existence of the falls, the levels of Lake Ontario have no effect on the levels of Lake Erie.

The outlet of Lake Ontario is the St. Lawrence River, in which are located the navigation locks, hydro-electric power generating stations and associated works of the St. Lawrence Seaway and Power Project. These facilities are used for the regulation of the river flow and the level of Lake Ontario, in accordance with Regulation Plan 1958D, by the International St. Lawrence River Board of Control under the supervision of the IJC. Downstream of Cornwall Island, the river is entirely within Canada. The flow passes through further power and navigation facilities into Lake St. Louis, through Montreal Harbour, and ultimately out into the Gulf of St. Lawrence.

Diversions

The diversions component of the study primarily focused on four existing major diversions:

1. The Ogoki Diversion takes water from the Ogoki River, which naturally drains through the Albany River into James Bay (at the southern end of Hudson Bay), and diverts it via Lake Nipigon and the Nipigon River into Lake Superior about 60 miles east of Thunder Bay, Ontario. The diversion is for hydro-electric power generation on the Nipigon River and the interconnecting waterways of the Great Lakes.

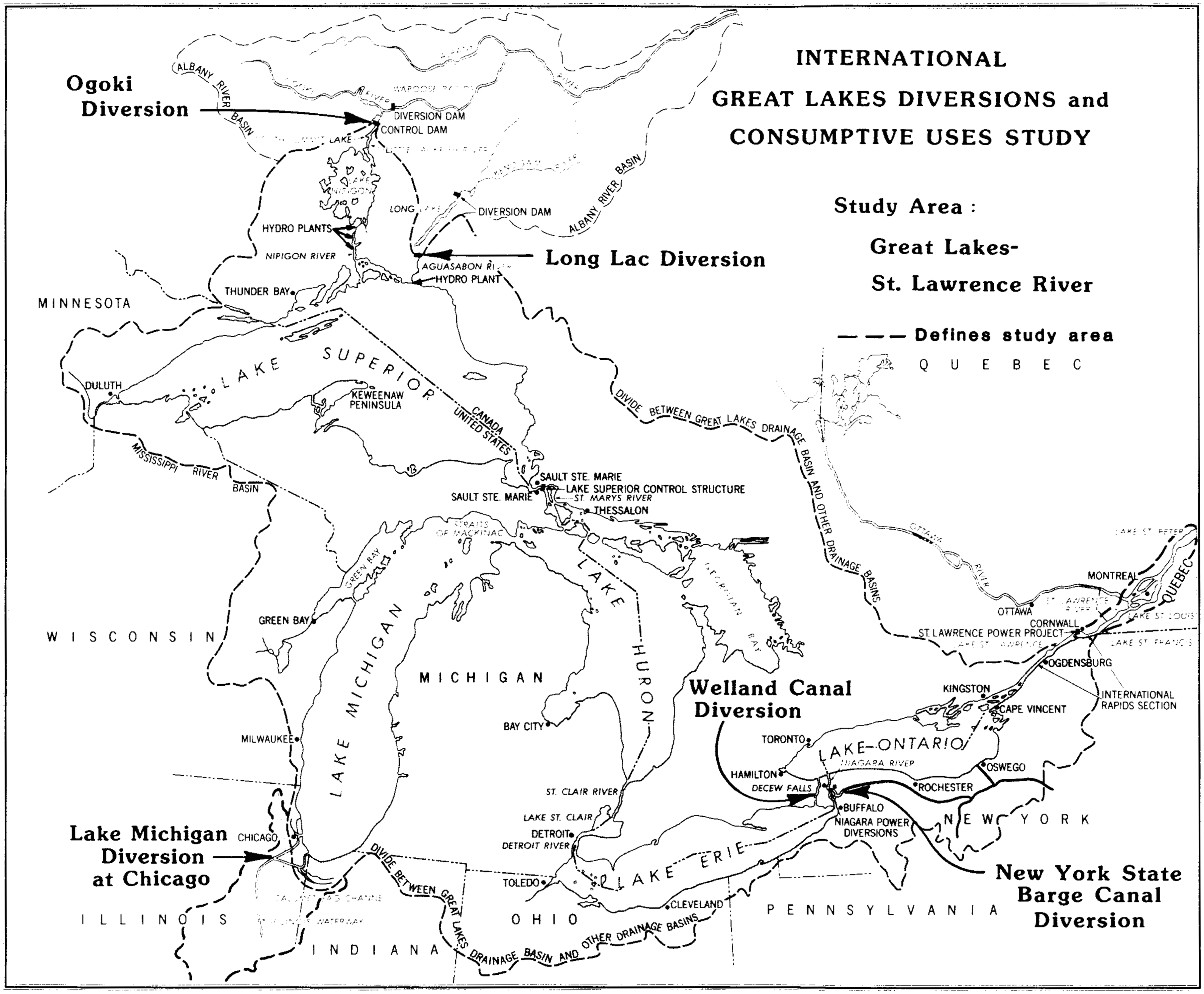
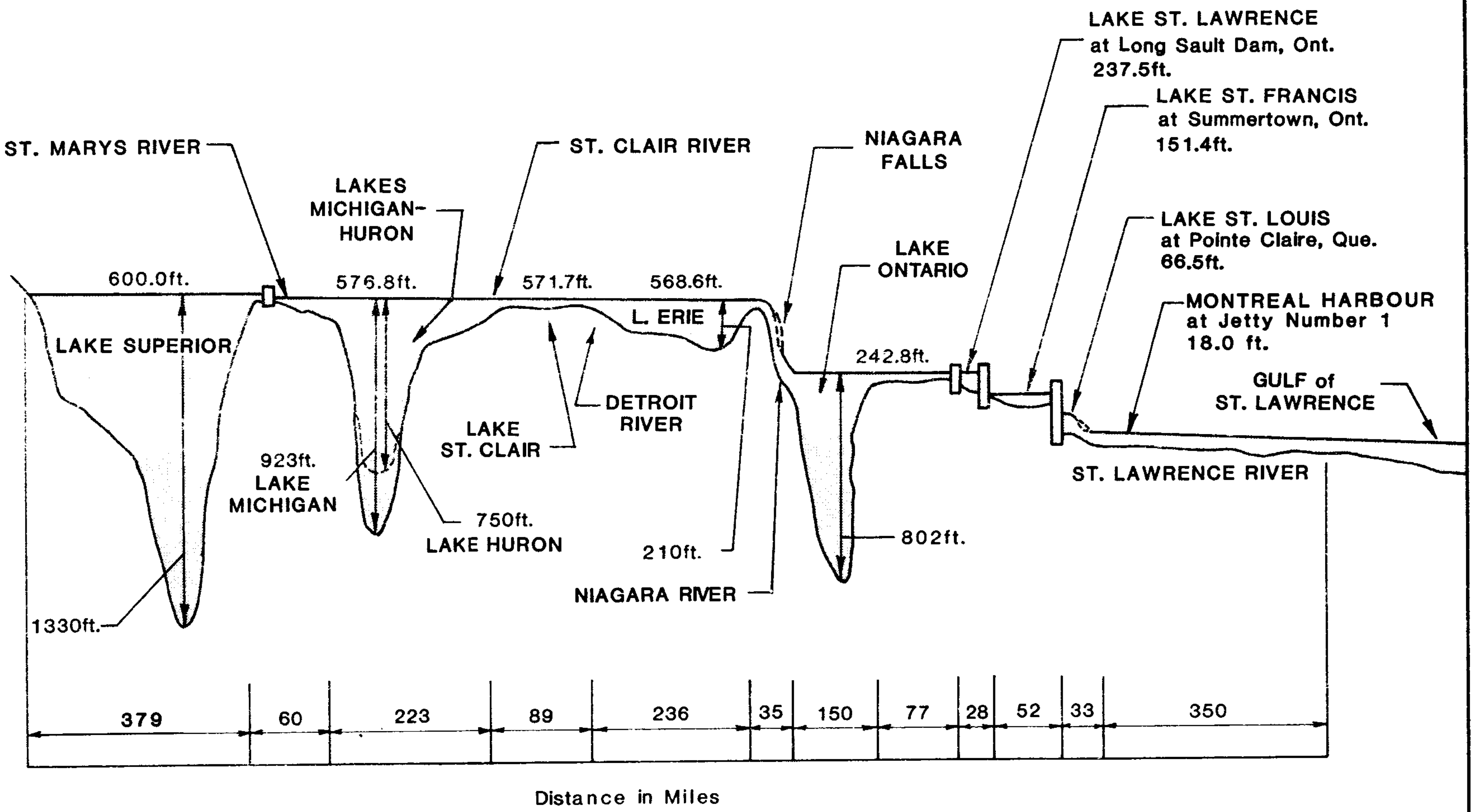

INTERNATIONAL
GREAT LAKES DIVERSIONS and
CONSUMPTIVE USES STUDY
Study Area :
Great Lakes-
St. Lawrence River
Defines study area
Ogoki Diversion
Long Lac Diversion
Welland Canal Diversion
Lake Michigan Diversion at Chicago
New York State Barge Canal Diversion
ALBANY RIVER BASIN
DIVERSION DAM
CONTROL DAM
LONG LAKE
DIVERSION DAM
ALBANY RIVER BASIN
HYDRO PLANTS
NIPIGON RIVER
AGUASABON RIVER
HYDRO PLANT
THUNDER BAY
MINNESOTA
DULUTH
LAKE SUPERIOR
KEWEENAW PENINSULA
CANADA
UNITED STATES
MISSISSIPPI RIVER BASIN
DIVIDE BETWEEN GREAT LAKES DRAINAGE BASIN AND OTHER DRAINAGE BASINS
QUEBEC
SAULT STE. MARIE
SAULT STE. MARIE
LAKE SUPERIOR CONTROL STRUCTURE
ST. MARYS RIVER
THESSALON
STRAITS OF MACKINAC
GREEN BAY
GREEN BAY
WISCONSIN
LAKE MICHIGAN
MICHIGAN
LAKE HURON
GEORGIAN BAY
BAY CITY
MILWAUKEE
ST. CLAIR RIVER
LAKE ST. CLAIR
DETROIT
DETROIT RIVER
CHICAGO
TOLEDO
LAKE ERIE
CLEVELAND
OHIO
ILLINOIS
INDIANA
DIVIDE BETWEEN GREAT LAKES DRAINAGE BASIN AND OTHER DRAINAGE BASINS
PENNSYLVANIA
NEW YORK
TORONTO
HAMILTON
DECEW FALLS
LAKE ONTARIO
NIAGARA RIVER
BUFFALO
NIAGARA POWER DIVERSIONS
ROCHESTER
OSWEGO
KINGSTON
CAPE VINCENT
OGDENSBURG
INTERNATIONAL RAPIDS SECTION
ST. LAWRENCE POWER PROJECT
CORNWALL
OTTAWA
OTTAWA RIVER
MONTREAL
QUEBEC
LAKE ST. PETER
LAKE ST. LOUIS
LAKE ST. FRANCIS

Figure 1



Elevations of the lake surfaces are given at low water datum, expressed on International Great Lakes Datum (1955). Horizontal and vertical scales have been distorted to convey visual impression.

PROFILE OF THE GREAT LAKES SYSTEM

Figure 2

2. The Long Lac Diversion connects the headwaters of the Kenogami River, which also originally drained through the Albany River into James Bay, and diverts the water via Long Lake and the Aguasabon River into Lake Superior near Terrace Bay, Ontario. The diversion provides water for driving pulpwood and for generating hydro-electric power on the Aguasabon River and the interconnecting waterways of the Great Lakes.

3. The Lake Michigan Diversion at Chicago takes water out of the Great Lakes system, for purposes of domestic and industrial water supply and navigation through the Chicago Sanitary and Ship Canal, and diverts it via the Illinois Waterway to the Mississippi River and thence to the Gulf of Mexico.

4. The Welland Canal Diversion takes water from Lake Erie at Port Colborne, Ontario, and diverts it across the Niagara Peninsula to Lake Ontario at Port Weller, Ontario, thus bypassing Lake Erie's natural outlet through the Niagara River. This water is primarily used to operate the deep-draft navigation canal and generate power at DeCew Falls.

The Board also examined a fifth diversion, the New York State Barge Canal, comprising the interconnected Champlain, Erie, Oswego, and Cayuga-Seneca Canals. This system takes water for navigation purposes from the Niagara River at Tonawanda, New York, and returns all of it to Lake Ontario at several tributaries and the Oswego Canal. Because this relatively small unregulated flow is withdrawn from the Niagara River at a point downstream of its natural hydraulic control, it has virtually no effect on the levels of Lake Erie and the other Great Lakes. There is, however, an impact on power; i.e., a reduction of water available for power generation on the Niagara River. Notwithstanding this, no detailed evaluation of this diversion was undertaken.

The Board found no federal, state or provincially sponsored or approved proposed new or changed diversions into, within or out of the basin of sufficient magnitude to have any material effects on water levels and flows of the basin. However, a number of very small such diversions came to the Board's attention during the study and are briefly discussed in the report.

A diversion of water out of the Great Lakes basin into an adjacent basin reduces the net water supplies and hence lake levels and outflows; a diversion into the Great Lakes basin raises them. Thus, the Long Lac/Ogoki Diversions constitute an increase in the water supply to Lake Superior and therefore to all downstream lakes. The Lake Michigan Diversion at Chicago reduces the supply to Lakes Michigan-Huron and thus to the remaining downstream lakes. The Welland Canal increases the outlet capacity of Lake Erie. These increases and decreases in the natural water supply produce corresponding increases and decreases in Great Lakes water levels and outflows. The regulation plans in effect on Lake Superior and Lake Ontario were designed to accommodate these diversions so as not to violate pertinent lake level criteria.

Basis-of-Comparison

In order to evaluate the hydrologic, economic and environmental effects of a change in the regime of Great Lakes levels and flows - whether due to consumptive uses, diversions management, regulation or any other form of intervention by man - it is first necessary to establish a base-line condition against which to measure such changes and their effects. This base-line condition is the basis-of-comparison. The actual levels and outflows during the selected period of record (1900 to 1976) cannot be used for this purpose because of physical and managerial changes that have occurred in the basin at different times over these years. Accordingly, the basis-of-comparison consists of the computed regime of levels and flows which would have prevailed, with the historic record of water supplies to the system, if present outlet channel configurations, assumed average diversion rates and present regulation plans for Lakes Superior and Ontario had existed constantly throughout the selected period of record. The average annual diversion rates were taken as 5,000 cfs at Long Lac/Ogoki, 3,200 cfs from Lake Michigan at Chicago, and 7,000 cfs through the Welland Canal.

During the course of the study, after the basis-of-comparison had been established, it was found that the long-term annual average of the combined Long Lac and Ogoki Diversions was actually 5,600 cfs. Also, in recent years the Welland Canal had increased to an annual average flow exceeding 9,000 cfs, while daily mean flows during the navigation season consistently approached canal capacity of 10,000 cfs. Accordingly, the long-term annual average Long Lac/Ogoki Diversions rate of 5,600 cfs and an estimated future Welland Canal average annual diversion rate of 9,400 cfs were also evaluated.

Hydrologic Evaluation Methodology and Results

To determine the present effects of an existing diversion, the procedure was to calculate a second set of lake levels and outflows, using the same historic water supply record, but with the average diversion flow removed from the Board's computer model of the Great Lakes system. Differences between this regime and the basis-of-comparison thus represent the effects of the diversion upon the system. The procedure was used similarly to calculate the effects on Great Lakes levels and outflows if a diversion flow at times were to be varied from its current average rate and, likewise, to calculate the effects of possible management scenarios involving variation of two or more diversions simultaneously. The purpose of examining alternative diversion management scenarios was to determine whether, by changing diversion flow rates, some amelioration of extreme lake levels could be achieved. As potential measures to reduce extreme high water levels, consideration was given to reducing the Long Lac/Ogoki Diversions to either 2,500 cfs or zero; increasing the Lake Michigan Diversion at Chicago to either 6,600 cfs or to its maximum possible annual average of 8,700 cfs; and increasing the Welland Canal Diversion to 9,000 cfs, which initially appeared to be the maximum possible. As a means of raising extreme low levels on Lake Erie, and to a lesser extent upstream lakes, consideration was given to a scenario in which the Welland Diversion would be decreased to 2,600 cfs by closing down power generation at the DeCew Falls plants. A decrease to zero is not a viable option since this would sever the Great Lakes shipping routes. The raising of extreme low lake levels by means of reducing the Lake Michigan Diversion at Chicago and/or increasing the Long Lac/Ogoki Diversions were found to be impractical options - the former due to its vital importance in supplying domestic and industrial water to the Chicago area and the latter because, when Lake Superior water supplies are abnormally low, similar hydrologic conditions usually prevail in the Albany River system and additional water is therefore unavailable for diversion to Lake Superior. It was not the mandate of the Board to consider diversion management alternatives that would require new structures or other physical modifications to change the hydraulic capacities of the diversions.

Forty-three possible management scenarios were investigated, comprising various combinations of alternative diversion flow changes. The concept adopted was that a reduction in net diversions inflow would be "triggered" when the natural water supply rises above its long-term mean value. Use of mean water supplies as a trigger mechanism, rather than mean water levels, was found to be more effective because supply changes precede and cause level changes and thus are an earlier indicator of developing hydrologic conditions.

Determination of the hydrologic impacts on the Great Lakes system of the existing diversions and of alternative diversion management scenarios involved comparisons of their regimes of levels and flows with that of the basis-of-comparison. These comparisons were made in terms of maximum, minimum and mean values, frequency of occurrence of extreme highs and lows at various times during the year (e.g., the navigation season, ice breakup in the spring, etc.) and other specific criteria governing the regulation plans for Lakes Ontario and Superior. The computed level and flow data were in turn used as an input to the economic and environmental evaluations.

The current rates of existing diversions have produced net increases in Great Lakes levels and outflows which are small in relation to their natural ranges. Their net effect has been to raise the mean levels of Lake Superior by 0.07 ft. and Lake Ontario by 0.08 ft., and to lower the mean levels of Lake Erie by 0.33 ft. and Lakes Michigan-Huron by 0.02 ft. By comparison, mean annual fluctuations in lake levels vary between 1.1 ft. on Lake Superior and 1.9 ft. on Lake Ontario.

With respect to possible alterations in diversion rates to reduce extreme high lake levels, the "maximum-effect diversion scenario" (Long Lac/Ogoki Diversions reduced to zero, Lake Michigan Diversion at Chicago increased to its maximum possible rate of 8,700 cfs, and the Welland Canal increased to 9,000 cfs) would lower maximum water levels by 0.10 ft. on Lake Superior, 0.57 ft. on Lakes Michigan-Huron, 0.45 ft. on Lake Erie, and 1.40 ft. on Lake Ontario. Any of the less drastic scenarios would result in smaller reductions in extreme lake levels.

Economic Evaluation Methodology and Results

Economic evaluations were carried out of the hydraulic effects on navigation, power generation, beaches and boating, and coastal zone interests. The latter includes erosion and inundation impacts on shore property. The principles underlying the evaluation techniques used are briefly as follows:

Commercial navigation generally benefits by higher water levels in the lakes and connecting channels. A decrease in mean water levels compels vessels to carry less cargo per trip, thereby increasing the total number of trips required to transport a given tonnage per year, and hence the cost of doing so. Since these economic losses could be eliminated if harbours and connecting channels were dredged deeper to offset a lowering of mean lake levels, the cost of such dredging was also evaluated.

The evaluation of the effects of a changed hydrologic regime on power generation was based on two factors. First, if the peak power load-meeting capability of Great Lakes hydro-electric generating facilities during the critical load demand period under a management scenario is less than under the basis-of-comparison, additional capacity would have to be installed, i.e., there would be an economic loss. Second, the reduction in average annual energy to each power system was evaluated in terms of the cost of obtaining equivalent energy from an alternative source.

Beaches were evaluated on the premise that changes in lake levels generate changes in beach areas and in the recreational opportunities they afford. Swimming was selected as the indicator activity; its monetary value can be estimated.

The boating evaluation involved determining the impacts on recreational boating activity, existing boating facilities, and commercial fishing. Only the United States side was studied. The monetary value was estimated as a function of the percentage of time small boats are inoperable due to water level changes, or taken as the cost of dredging to allow them to operate the same as under basis-of-comparison conditions, whichever was the least cost alternative.

The procedure for evaluating the impacts on shore property due to erosion assumed that the amount of material eroded from a bluff is directly related to the wave energy reaching the toe of the bluff. This energy is dependent on wind speed and direction, shoreline physiographic parameters, and prevailing water levels. Changes in the latter alter the rate of erosion. Monetary damages were computed as a function of the wave energy. The evaluation of inundation along the shoreline was based upon a stage-damage-frequency method which has been successfully applied to numerous river systems. The primary parameters were available recorded damage data, water levels and physiographic data. Inundation is an event type process and the evaluation procedure involved determining, on a monthly basis, the probabilities of short-term rises occurring at different mean water levels to produce peak storm water levels and consequent flooding.

Damages are caused to marine structures by both high and low water levels. Extreme low water increases the frequency of exposure of normally submerged untreated timber substructures, which accelerates decay and thus reduces a structure's useful life. There is a further economic detriment in the restricted access to structures due to reduced navigable depths. Extreme high water can also result in losses due to inundation of the land approach to some smaller structures, as well as possible physical damage or destruction.

With respect to water intakes for shoreline industries and communities, the effect of low lake levels is to increase pumping costs and, in the extreme, cause pump impeller cavitation. Shallow water decreases the quality of the intake water because of increased turbidity as a result of wave action transporting more bottom sediments; it also increases the risk of certain ice problems. High lake levels may erode or inundate the foundation of a lake-side plant. Of these effects, it was only possible to quantify increased pumping costs.

Of the total array of scenarios, the hydrologic results of ten were selected for economic evaluation. Of these, three were evaluations of the sensitivity of the basis-of-comparison. Of the remainder, the only one producing an overall annual net benefit is that which increases the Welland Canal flow from 7,000 to 9,000 cfs, while keeping the other diversions at their current rates; as previously noted, however, this scenario has become a fact during the course of this study. The evaluation shows benefits to coastal zone interests of about $0.6 million, power interests of about $1.0 million, and recreational beaches and boating interests (United States side below Port Huron, Michigan only) of about $0.3 million, but a loss to navigation interests of about $0.6 million, for a net benefit of about $1.3 million. The other six scenarios would produce net losses ranging from $2.8 million to $69.5 million annually. The "maximum-effect diversion scenario" would generate annual economic benefits to coastal zone interests ($6.0 million) and recreational beach users ($1.8 million); however, it would cause economic losses to navigation ($13.8 million), power ($61.3 million), and recreational boating interests ($1.6 million). For this scenario, the net economic loss to the users of the system would be therefore of the order of $69 million annually.

Environmental Evaluation Methodology and Results

The environmental evaluation was limited by inadequate ecological and other relevant data. More detailed and costly environmental studies, entailing extensive field work, would not be justified unless some feasible management scenario emerged which warranted subsequent development of a positive plan of action. In any event, the Board examined the subjects of fisheries, wildlife/wetlands and water quality.

In the case of fisheries, the probable effects of the management scenarios were evaluated through a review of published literature. Emphasis was placed on identifying the requirements of the fish populations for specific nearshore habitat, especially wetlands and shallow embayments, and identifying the fish species which require, in summer, the cool water of the hypolimnion.

A measure of the value of the lower Great Lakes fisheries was established from the value of the commercial and sport fisheries. Descriptions of the nearshore habitat were obtained from the literature, unpublished inventories and topographic sheets. Estimates of changes in wetland types, and hypolimnion changes related to water levels, were obtained from the wildlife and water quality studies.

The probable effects on wildlife were evaluted by analysis of the impacts that water level changes would have on wetlands. Shoreline wetlands in the lower Great Lakes were inventoried and classified according to seven distinctive wetland types. Listings were made of wetland-dependent birds, mammals, reptiles and amphibians found in the study area and of their habitat. Changes in water levels were related to changes in wetland areas and hence to the effects on the wildlife using them.

The water quality evaluation included an examination of the following characteristics: hypolimnion volume and oxygen resources, general lake water quality, phosphorus and turbidity concentrations, cladophora production, embayment water quality, and waste dispersion capability. Since the nearshore is the most important lake area for wildlife, fish production and various human activities, the water quality study placed emphasis on effects in these areas rather than in mid-lake.

The following summarizes the environmental evaluation. Implementation of the maximum-effect diversion scenario should not produce any significant social effects. Population growth trends would not be directly affected; however, adverse impacts on waterborne commerce and power production could induce population shifts. Hunting pressure could shift from wetland-dependent game to upland species. Non-consumptive wildlife-related recreation could experience a slight decline. Beach recreation would likely benefit by more exposed shoreline, but recreational boating could be negatively affected due to a reduction in water depth in shallow areas such as the connecting channels, harbours and bays. Adverse impacts to the sport fishery could also be incurred by lowered water levels. Water quality would not be significantly affected.

Consumptive Uses

The consumptive uses component of the study involved a determination of present water withdrawals and consumptive uses, together with projections from a base year of 1975 to 2035. Withdrawal and consumption quantities were developed in a breakdown by lake basins, nations, sectors of the economy, and lake and non-lake categories (i.e., water taken directly from the lakes, or from inland sources such as tributary streams and groundwater, respectively). Seven sectors were considered: municipal, rural-domestic, manufacturing, mining, rural-stock, irrigation and thermal power generation.

Water withdrawal quantities are generally metered and provide a basis from which to derive estimates of consumptive uses. Withdrawals in 1975 were extremely large (75,600 cfs) in comparison with consumptive uses

(4,900 cfs). Consumptive uses as a percentage of withdrawals from each lake ranged from 4.8 to 10.4 percent. Lakes Michigan and Erie had by far the highest withdrawals and uses.

In developing reasonably foreseeable future projections of withdrawals and consumptive uses, it was necessary to adopt a variety of general assumptions, based on information and advice from appropriate authorities. These assumptions related to such parameters as trends in population growth and migration, employment levels, GNP, per capita consumption, economic growth, energy use and governmental policies. Based on these assumptions, a most likely projection (MLP) was developed for each of the seven water use sectors. However, realizing that in any long-range economic forecasting even the most realistic of assumptions are debatable and become increasingly tenuous when applied further into the future, the Board also tested the sensitivity of the assumptions on the computed estimates. This was done by varying some of the more significant assumptions, within a reasonable range of possibilities, to produce alternative high and low projections and thus define a band of probable future values centered on the MLP. It is a measure of the inherent uncertainty in forecasting economic scenarios that the high and low projections of total consumptive use in the year 2035 are about ±40 percent of the MLP value.

United States municipal water use projections were based on the 1975 National Water Assessment, but with some modifications. The Canadian projections were related to population forecasts, obtained from the province of Ontario, by applying withdrawal and use coefficients. The two methods are roughly similar, despite some differences in detail, because demographic projections prepared by central statistical agencies underlie both.

In both countries, water for rural domestic use is largely drawn from wells, inland streams, reservoirs and other non-lake sources; it is relatively small and has virtually no effect on Great Lakes levels. Estimates were based on rural population forecasts and per capita rates of consumption.

The manufacturing water use sector represents the withdrawal and consumption of Great Lakes water by users traditionally considered as part of heavy industry. Such users may be either self-supplied or supplied from central systems. Manufacturing is the largest consumer of water in the basin, the abundance of water being the primary reason that this region of the United States is so heavily industrialized. The Great Lakes basin is likewise the most important industrial area in Canada. Increases in manufacturing consumptive uses indicated in this study are primarily dependent on assumptions concerning technological changes in the various industries involved and the institution of closed recycling systems for cooling and process water, in response to clean water laws, water availability and economic feasibility. The United States MLP assumed that new industries will meet the original requirements of the 1972 Clean Water Act; in contrast, the Canadian MLP held the recirculation and consumption rates constant. In most other respects, the complex modelling approaches in each country were substantially the same.

Water is used for a variety of mining processes, including metals, non-metallic minerals and mineral fuels. The Great Lakes supply about 80 percent of mining water requirements in the basin. Methodologies for developing both United States and Canadian figures were based on water use per production dollar in each mineral sector and projections were tied to each country's economic climate.

Rural stock water use refers to the withdrawal and consumption of water for the feeding and sanitation of livestock. Consumption, which is a comparatively minor portion of the total demand on the Great Lakes basin, includes animal drinking water, evaporation from stockwater ponds and losses of cleaning and waste water. The United States methodology projected the number of different types of animals on the basis of population growth rates and presumed a direct relationship with demand. The Canadian methodology was based on per capita meat and dairy products demand.

Irrigation water, which is also a comparatively minor demand on the basin, is primarily drawn from non-lake sources. It includes the watering of crops, pastures, orchards, golf courses and public lands such as parks and forests.

In this study, water for power generation refers to that which is required for cooling purposes in thermal-electric power generating stations; consumptive use in hydro-electric generation is insignificant and has therefore not been considered. Water for thermal plant cooling currently represents the most significant demand on the Great Lakes in terms of withdrawal and, by the end of the projection period, will become the dominant type of consumption. The majority of older thermal-electric power generating plants utilize once-through condenser cooling systems having high water withdrawals and only minimal measured consumptive losses (although some additional consumption occurs due to increased evaporation of heated water after it is discharged to lakes and streams). In more recent years there has been increased use of "wet" cooling towers in the United States to dissipate waste heat via the evaporation of a portion of the water flowing through the tower. This process reduces withdrawals, but it is significantly more consumptive. Thus, as old plants are phased out and new plants are constructed, projected total water withdrawal rates for power generation will decrease, while consumptive use will substantially increase. Although new technology has provided the alternative of "dry" (air cooled-radiant heat transfer) cooling towers, the process is currently not economically viable since the cooling technology is considerably less efficient and consumes considerable energy resources.

A summary of the consumptive uses forecasts is given below. (All figures are in cfs.)

Use Sector	1975	2000 High	2000 MLP	2000 Low	2035 High	2035 MLP	2035 Low
Municipal	830	1,400	1,100	910	2,600	1,600	1,300
Rural-Domestic	330	390	390	380	450	450	440
Manufacturing	2,500	5,900	4,600	4,000	14,200	9,500	7,000
Mining	240	340	340	340	530	500	490
Rural-Stock	210	280	250	230	410	360	310
Irrigation	350	700	630	620	1,200	1,000	1,000
Power	480	2,700	2,600	1,500	17,100	12,000	5,800
TOTAL	4,900	11,900	9,900	8,000	36,500	25,400	16,300
Country							
United States	4,300	9,900	8,500	6,800	28,000	20,900	13,300
Canada	600	2,000	1,400	1,200	8,500	4,500	3,000

Note: All totals have been rounded to the nearest hundreds.

It should be noted that the gradually increasing consumptive uses of water contributes to a gradual decrease in the net water supplies to the Great Lakes basin which, in turn, lowers the levels of the lakes and reduces their outflows, a consequence which is cumulatively greater downward through the chain of Great Lakes. The MLP projection of total consumptive uses in 2035 represents an increase of 20,500 cfs from 1975. This increase is equivalent in magnitude to 8.6 percent of the mean outflow of the St. Lawrence River. The impacts (in feet) on the mean levels of the unregulated lakes are as follows:

Lakes	High	MLP	Low
Michigan-Huron	-1.06	-0.73	-0.38
Erie	-1.13	-0.76	-0.38

TABLE OF CONTENTS

TABLE OF CONTENTS (CONT.)

TABLE OF CONTENTS (CONT.)

PAGE NO.

Section 4

EXISTING DIVERSIONS

TABLE OF CONTENTS (CONT.)

TABLE OF CONTENTS (CONT.)

TABLE OF CONTENTS (CONT.)

TABLE OF CONTENTS (CONT.)

TABLE OF CONTENTS (CONT.)

LIST OF TABLES

LIST OF TABLES (CONT.)

PAGE NO.

LIST OF TABLES (CONT.)

LIST OF FIGURES

LIST OF FIGURES (CONT.)

LIST OF FIGURES (CONT.)

LIST OF ANNEXES TO MAIN REPORT

ANNEX A

Text of February 21, 1977 Reference from the Governments of the United States and Canada.

ANNEX B

Text of the International Joint Commission Directive of May 10, 1977 to the International Great Lakes Diversions and Consumptive Uses Study Board.

ANNEX C

Series of Newsletters "Diversions", and Report on Public Workshops.

ANNEX D

Prior Reports that were Pertinent or of Special Interest to this Study.

ANNEX E

State, Provincial and Federal Agencies that Participated in this Study, Including a Listing of Participants.

ANNEX F
(bound separately)

Consumptive Water Use - A Documentation of the Methodology used in Consumptive Use Projections.

ANNEX G

(bound separately)

Evaluation of Diversion Management Scenarios and Consumptive Water Use Projections- A Documentation of the Detailed Hydrologic, Economic and Environmental Evaluation of Selected Diversion Management Scenarios and the Hydrologic Evaluations of Consumptive Water Use Projections.

LIST OF APPENDICES TO MAIN REPORT

(bound separately)

APPENDIX A - COORDINATED BASIC DATA

A documentation of the coordinated basic data developed and employed in this study. It describes the methods and techniques employed in obtaining the water supply data and development of the basis-of-comparison. It also contains tabulations of the final basis-of-comparison data and tabulations of the basic data employed in their derivation.

APPENDIX B - COMPUTER MODELS-GREAT LAKES

A documentation of computer "software" containing a complete program listing of one program developed uniquely for this study as well as a tabulation of two standard programs used. The programs themselves are stored in the United States at the offices of the Detroit District, Corps of Engineers, Detroit, Michigan, and in Canada at the offices of the Inland Waters Directorate, Federal Department of the Environment, Ottawa, Ontario.

APPENDIX C - DIVERSION MANAGEMENT SCENARIOS

A documentation of the monthly mean levels and flows data of 13 diversion management scenarios selected for detailed hydrologic evaluation.

INTERNATIONAL GREAT LAKES DIVERSIONS AND CONSUMPTIVE USES STUDY

Section 1

INTRODUCTION

1.1 Purpose and Authority

By a Reference dated October 7, 1964, the Governments of Canada and the United States requested the International Joint Commission (IJC) to study the various factors which affect the fluctuations of the water levels of the Great Lakes and to determine whether measures could be taken to further regulate the Great Lakes so as to bring about a more beneficial range of stage. As a result of this Reference, the IJC established the International Great Lakes Levels Board (IGLLB) in 1964 to conduct the study. That Board submitted its report to the IJC in 1973.

Upon completion of the Board's study and report, dated December 7, 1973, the IJC, in 1976, submitted its report "Further Regulation of the Great Lakes" to the Governments. The IJC identified diversions into, out of and within the Great Lakes basin and consumptive uses of water as two of the factors affecting lake levels. For the purpose of studying improved regulation plans, the Levels Board's study assumed existing diversions to be constant over the study period at their current average annual rates. The effects of the current and projected consumptive use of water were considered but not investigated in detail. Therefore, the IJC recommended that these two subjects should be examined more closely. The Governments agreed and, by a Reference dated February 21, 1977 (full text, Annex A), requested the IJC "...to examine into and report upon the following matters which have, or may have, material effects on water levels and flows of the Basin, including the international and Canadian reaches of the St. Lawrence River:

1. Existing and reasonably foreseeable patterns of consumptive uses of Great Lakes waters;

2. Existing diversions, including the Welland Canal and the New York State Barge Canal, and federal, state or provincially sponsored or approved proposed new or changed diversions, within, into or out of the Basin, and, in particular,

3. Existing diversions at Chicago and at Long Lac/Ogoki, and the proposed study and demonstration program authorized by United States P.L. 94-587 affecting the rate of diversion at Chicago."

To carry out this study, the IJC established the International Great Lakes Diversions and Consumptive Uses Study Board on May 3, 1977. The Commission's instructions to the Board were set out in its Directive of

May 10, 1977 (Annex B). The Directive instructed the Board to "in particular assess the effects of varying the rate of existing diversions during periods of extreme levels on the Great Lakes." A Plan of Study was developed by the Board and approved by the Commission on January 5, 1978.

This report to the IJC has been prepared to present the Board's findings, conclusions, and recommendations on its study of diversions and consumptive uses conducted in accordance with the Reference and Directive cited.

1.2 Constraints and Assumptions

This study assumes no changes in the present physical capacities of the existing diversions. Maximum and minimum flow limits of each diversion (current and proposed) are consistent with past experience. Within these limits, the effects of changes in diversion rates on Great Lakes levels and outflows over the full range of water supply conditions were determined.

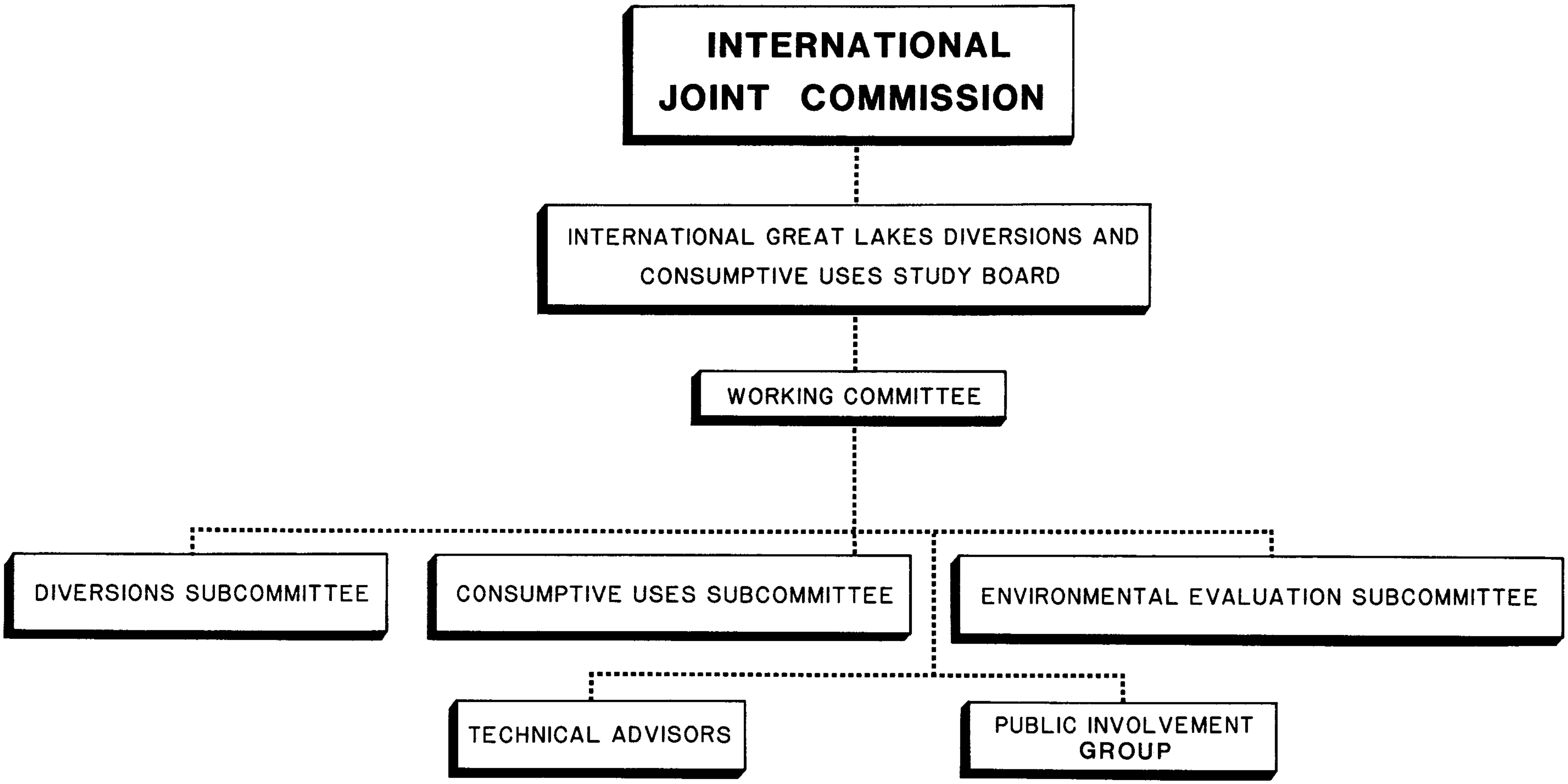
For the purpose of determining the quantities of diversions and consumptive uses, it was assumed that the Great Lakes basin consists of the lakes and the streams tributary thereto. However, impacts were determined only for the lakes, connecting channels and outflow rivers. Additionally, in the case of diversions, particularly the Lake Michigan Diversion at Chicago, the Long Lac/Ogoki Diversions and the Welland Canal, impacts were considered wherever they occurred.

Since time constraints precluded extensive field surveys, only existing data, and data which became readily available during the course of the study, were used.

1.3 Study Organization and Coordination

The International Great Lakes Diversions and Consumptive Uses Study Board organizational structure is shown on Figure 1-1. The functions of the Board and each of the supporting elements of the Board are discussed below. The Board gave guidance to its Working Committee with respect to study direction, reported to the IJC on study progress, and was solely responsible for the study report content. The Working Committee organized activities and directed the necessary investigations to reply to the Study Board's Directive.

The Diversions Subcommittee was responsible for all technical studies related to the hydraulics and hydrology of the system. It was also responsible for determining the effects of the current diversion rates on the Great Lakes system and for developing possible management scenarios for varying these diversions. Further, the subcommittee was responsible for determining the hydrologic impacts of present and probable future consumptive uses within the Great Lakes.



Structure of Study Organization

NOTE: see Annex E for list of participating agencies

Figure 1-1

The Consumptive Uses Subcomittee addressed itself to assessing the present and probable future consumptive uses within the Great Lakes basin.

The Environmental Evaluation Subcommittee evaluated the environmental and social impacts of the diversion management scenarios.

The Public Involvement Program Ad-Hoc Group developed and assisted in carrying out a public involvement program.

At the time that the IJC was directed to conduct a study of Great Lakes diversions and consumptive uses, it was also directed to conduct a study to determine the feasibility of limited regulation of Lake Erie. To ensure that the progress and results obtained from these two studies were fully coordinated, liaison was carried out by individuals who served both Boards through joint membership. Further, since much of the work of the two Study Boards was identical, their Plans of Study were coordinated to avoid duplication of effort between the studies. Also, the Diversions and Consumptive Uses Board relied heavily on the Lake Erie Regulation Study Board for the economic and partial environmental evaluation of diversion management scenarios. Liaison was maintained with the IJC's Great Lakes Boards of Control. Liaison was also established with members of the Chicago District of the Corps of Engineers who are conducting a study entitled, "Increased Lake Michigan Diversion at Chicago Demonstration and Study Program." That study was authorized by the U.S. Congress for the purpose of investigating the feasibility of increasing the amount of water diverted from Lake Michigan at Chicago into the Illinois Waterway during periods of above normal Lake Michigan levels.

1.4 Public Participation

The International Joint Commission, as part of its policy of keeping the public informed of its study activities, held a series of public hearings during 1977. The Board was in attendance at these hearings and was directed by the IJC to keep the public informed as the study progressed.

To comply with this directive a Public Involvement Program Ad-Hoc Group was established in April 1978. It was given the task of preparing and instituting a public involvement action plan appropriate to the needs of the study. The objectives of the plan developed were:

a. To inform all interested people and groups of the study's purpose, scope, progress, and findings;

b. To present for public review and comment the most promising diversion management scenario considered by the Study Board and the projected trends for water withdrawal and consumptive use to the year 2035; and,

c. To assess public input and incorporate it into the Board's findings as appropriate for presentation to the IJC.

These goals were achieved through the use of a series of newsletters entitled "Diversions", news releases to the media, and a series of public workshops held in May 1980 at various locations within the Great Lakes basin. The newsletters were published in both English and French. The newsletters and a report on the workshops are included in Annex C.

1.5 Other Studies

Ongoing studies that were pertinent or of special interest to this study included the following:

a. The International Lake Erie Regulation Study - This study was conducted by a Board established by the IJC to determine the possibilities for limited regulation of Lake Erie, consistent with the principle of systemic regulation of the Great Lakes. The study was directed by a February 21, 1977 Reference from the Governments of the United States and Canada to the IJC.

b. Increased Lake Michigan Diversion at Chicago Demonstration and Study Program - This study was carried out by the Chicago District, Corps of Engineers, under authority of Section 166 of the U.S. Water Resources Development Act of 1976 (P.L. 94-587). The purpose of the study and demonstration was to test the practicability of increasing the Lake Michigan Diversion up to 10,000 cfs during times when Lake Michigan levels would be above its long-term average, to alleviate shoreline damage on the Great Lakes caused by high lake levels and to improve the water quality of the Illinois Waterway.

c. The International St. Lawrence River Board of Control's continuing studies relating to regulation of the levels and outflows of Lake Ontario, the International Rapids Section of the St. Lawrence River and downstream.

Prior reports that were pertinent or of special interest to this study are listed in Annex D.

1.6 Acknowledgements

The preparation of this report was a joint cooperative effort of the various state, provincial and federal agencies listed in Annex E. Acknowledgement is extended to members of those agencies who were represented on the Study Board, Working Committee, and Subcommittees. Also, acknowledgement is extended to members of the Study's Public Involvement Program Ad-Hoc Group, Technical Advisors to the Working Committee, and observers to the Working Committee. Further, acknowledgement is extended to the International Lake Erie Regulation Study Board, whose Coastal Zone, Navigation, and Power Subcommittees completed the economic evaluation of the selected diversion management scenarios presented herein.

Section 2

RESOURCES AND ECONOMY OF THE STUDY AREA

2.1 Great Lakes, Outflow Rivers and Hydrologic Boundaries

The Great Lakes and their connecting channels extend roughly west to east. The land area contiguous to the Great Lakes is linked to the Great Lakes by rivers and channels forming a single drainage system which flows into the St. Lawrence River and thence to the Atlantic Ocean.

2.1.1 Study Area

The study area encompasses the Great Lakes-St. Lawrence River system from the westerly end of Lake Superior to Trois-Rivieres on the St. Lawrence River, about 80 miles downstream from Montreal. This system is bordered by eight states -- Minnesota, Wisconsin, Illinois, Indiana, Michigan, Ohio, Pennsylvania, and New York -- and by the provinces of Ontario and Quebec. The five Great Lakes -- Superior, Michigan, Huron, Erie, and Ontario -- with their connecting rivers, and Lake St. Clair, have a water surface area of about 95,000 square miles. A map of the study area is shown in Figure 2-1.

2.1.2 Level Datum

The present water level datum used on the Great Lakes is known as the International Great Lakes Datum-1955 (IGLD-1955). It measures the difference in elevation between sea level at Father Point, Quebec, and any point in the basin. This datum was developed to provide Canadian and U.S. agencies with an official datum, acceptable to both countries, on which design and operation of the St. Lawrence Seaway and Power Project could proceed. Over a period of time, gauge relationships have identified a differential movement of the earth's crust in the Great Lakes region which affects the relationship between the actual water level at a given place and the elevation indicated by the reading of a gauge at the same location. Because of this crustal effect, it has become important to show the year in which the datum elevations are assigned. With the passage of time, it may become necessary to adjust the reference elevation at the gauge to allow for its movement with respect to Father Point during the intervening period.

Low water datum (LWD) on each lake is the water level to which depths on navigation charts and harbour and channel improvements on the Great Lakes are referred. The elevations of LWD for the Great Lakes are shown in Table 3-4 and the profile in Figure 2-2.

2.1.3 Lake Superior and St. Marys River

Lake Superior, the uppermost and largest of the Great Lakes, discharges through the St. Marys River into Lake Huron, shown in Figure

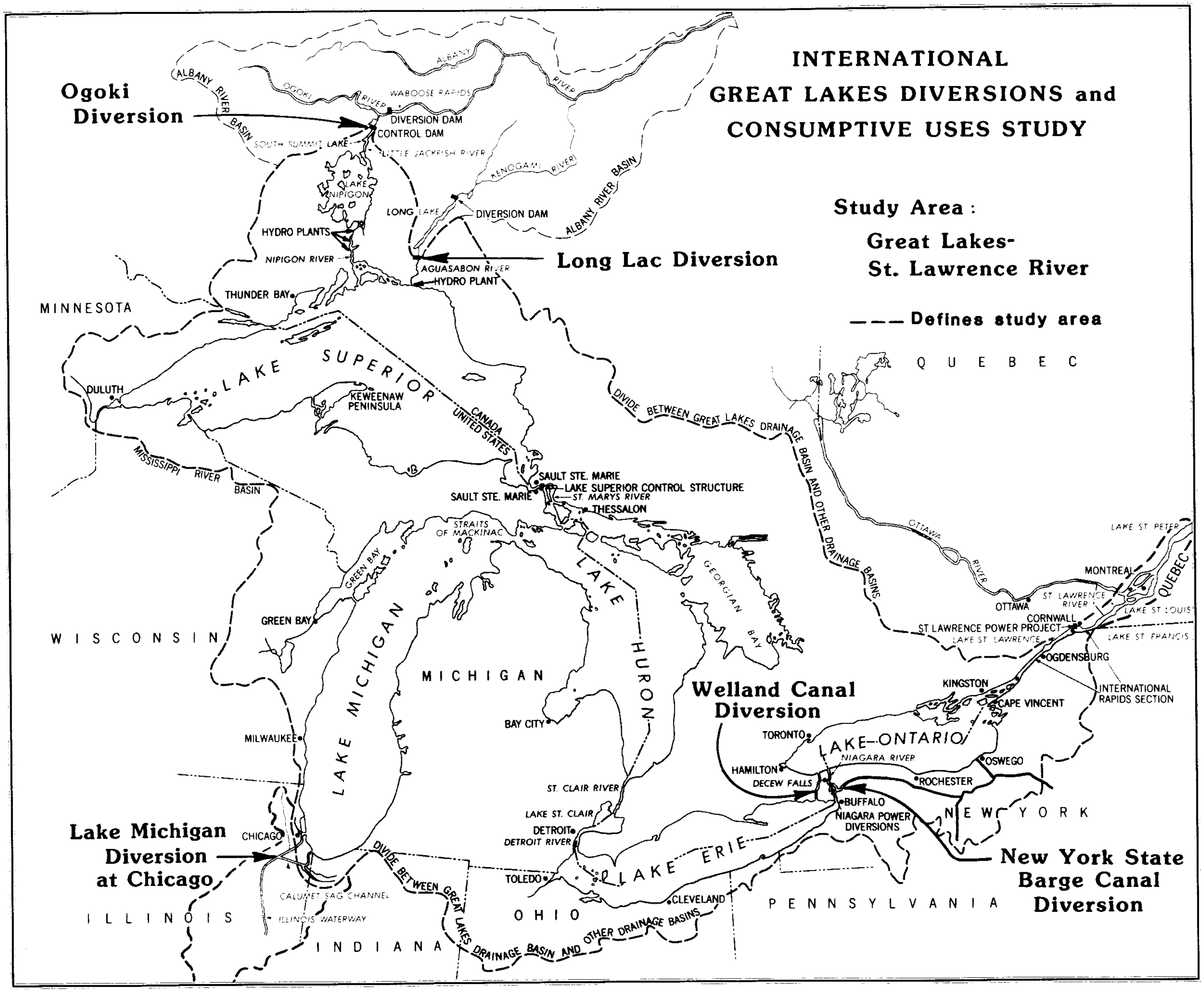
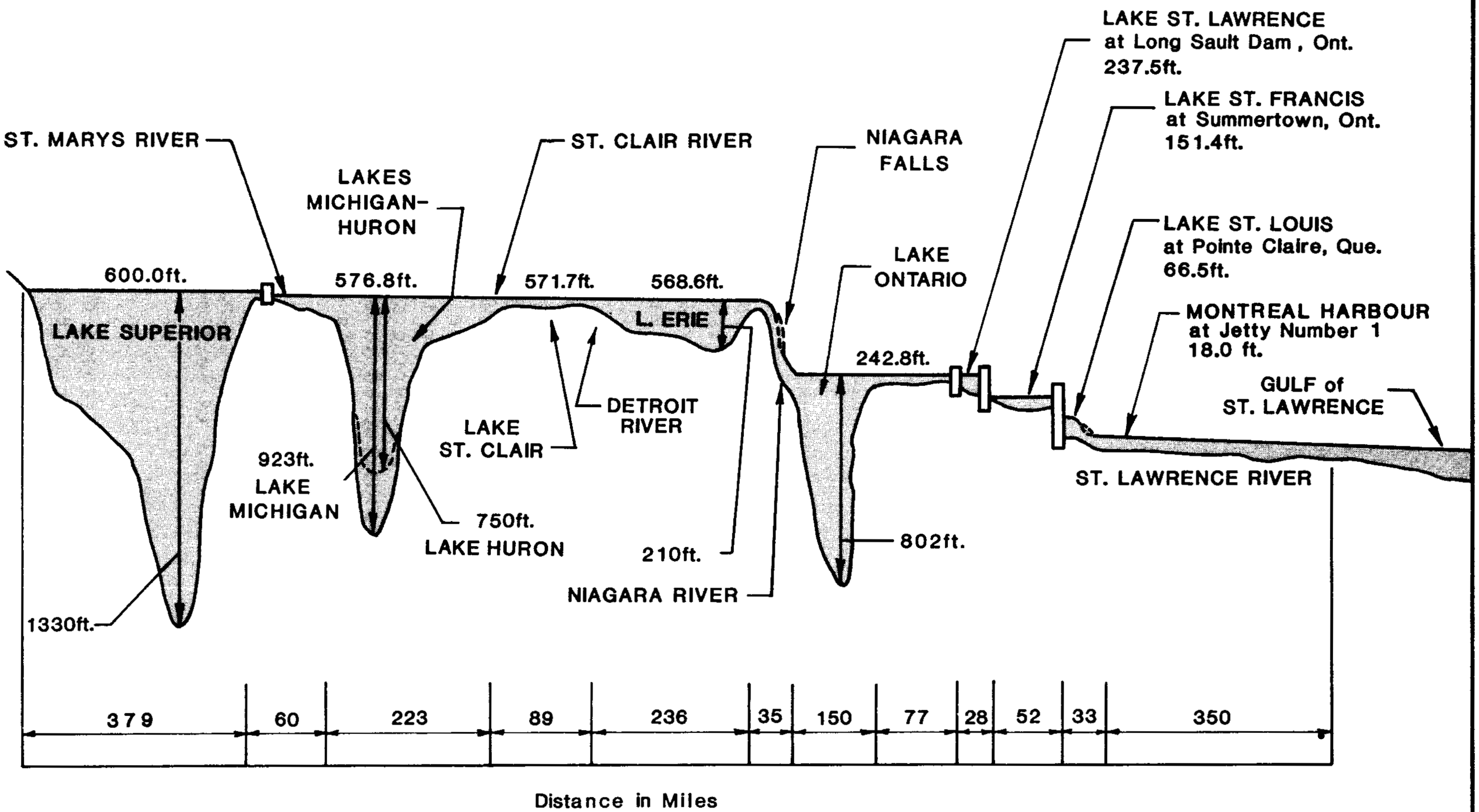

INTERNATIONAL
GREAT LAKES DIVERSIONS and
CONSUMPTIVE USES STUDY
Study Area :
Great Lakes-
St. Lawrence River
Defines study area
Ogoki
Diversion
Long Lac Diversion
Welland Canal
Diversion
Lake Michigan
Diversion
at Chicago
New York State
Barge Canal
Diversion
ALBANY RIVER
ALBANY RIVER BASIN
OGOKI RIVER
WABOOSE RAPIDS
DIVERSION DAM
CONTROL DAM
SOUTH SUMMIT LAKE
LITTLE JACKFISH RIVER
KENOGAMI RIVER
LAKE NIPIGON
LONG LAKE
DIVERSION DAM
HYDRO PLANTS
NIPIGON RIVER
AGUASABON RIVER
HYDRO PLANT
THUNDER BAY
MINNESOTA
LAKE SUPERIOR
DULUTH
KEWEENAW
PENINSULA
CANADA
UNITED STATES
MISSISSIPPI RIVER BASIN
DIVIDE BETWEEN GREAT LAKES DRAINAGE BASIN AND OTHER DRAINAGE BASINS
QUEBEC
OTTAWA RIVER
SAULT STE. MARIE
LAKE SUPERIOR CONTROL STRUCTURE
ST. MARYS RIVER
THESSALON
SAULT STE. MARIE
STRAITS OF MACKINAC
GREEN BAY
GEORGIAN BAY
LAKE HURON
LAKE ST PETER
MONTREAL
ST LAWRENCE RIVER
OTTAWA
LAKE ST LOUIS
CORNWALL
ST LAWRENCE POWER PROJECT
LAKE ST LAWRENCE
LAKE ST FRANCIS
OGDENSBURG
INTERNATIONAL
RAPIDS SECTION
WISCONSIN
GREEN BAY
LAKE MICHIGAN
MICHIGAN
KINGSTON
CAPE VINCENT
BAY CITY
MILWAUKEE
TORONTO
LAKE ONTARIO
NIAGARA RIVER
OSWEGO
HAMILTON
DECEW FALLS
ROCHESTER
BUFFALO
ST. CLAIR RIVER
LAKE ST. CLAIR
NIAGARA POWER
DIVERSIONS
NEW YORK
CHICAGO
DETROIT
DETROIT RIVER
TOLEDO
LAKE ERIE
CALUMET SAG CHANNEL
ILLINOIS WATERWAY
CLEVELAND
ILLINOIS
OHIO
PENNSYLVANIA
INDIANA

Figure 2-1



Elevations of the lake surfaces are given at low water datum, expressed on International Great Lakes Datum (1955). Horizontal and vertical scales have been distorted to convey visual impression.

Figure 2-2

PROFILE OF THE GREAT LAKES SYSTEM

2.2. In the upper 14 miles, the river falls approximately 0.2 foot; in the next 0.75 mile through the St. Marys Rapids, it falls approximately 20 feet. The remaining fall, about two feet, takes place in the 48 miles between the foot of the rapids and Detour Passage at Lake Huron. Because of this very mild slope to Lake Huron, the water levels at the foot of the rapids in the vicinity of Sault Ste. Marie are affected by the levels of Lake Huron. To compensate for the effect on Lake Superior levels of power diversions around the St. Marys Rapids, a gated dam was constructed across the St. Marys River at the head of the rapids. Since the completion of this dam in 1921, the discharge from Lake Superior has been fully regulated and is under the supervision of the IJC through its International Lake Superior Board of Control.

The natural supply to Lake Superior has been augmented by diversions from the Albany River basin through the Long Lac and Ogoki Projects in Canada. Subsection 4.2 gives further details. The present Lake Superior regulation plan accommodates these diversions within the IJC criteria for the regulation of the lake.

2.1.4 Lakes Michigan-Huron and St. Clair-Detroit Rivers

Lakes Michigan and Huron stand at virtually the same level, because they are connected by the broad and deep Straits of Mackinac. They are usually treated as one lake in hydrologic and hydraulic considerations. The natural outlet for the discharge from these lakes is through the St. Clair River, Lake St. Clair and the Detroit River into Lake Erie, which is approximately eight feet lower than the level of Lakes Michigan and Huron. The slopes of water surface profiles along the St. Clair and Detroit Rivers are relatively uniform and there are no rapids or falls. The flow out of Lake Huron is a function of the levels of both lakes, i.e., the levels of Lake Erie have an effect on the levels of Lake Huron. Removal of sand and gravel for commercial purposes, together with dredging to increase depths in navigation channels in these rivers, has increased their discharge capacity. During the last dredging program in the St. Clair River, excavated material was placed at strategic points in the river to compensate partially for the water level lowering effects caused by the dredging. Compensating dikes were constructed in the lower Detroit River to offset, partially, the lowering of water levels due to past navigation improvements.

Water is diverted from Lake Michigan at Chicago, Illinois, into the Mississippi River basin. Further details concerning the hydraulics of the Lakes Michigan-Huron system are presented in Sections 3 and 4.

2.1.5 Lake Erie and Niagara River

The natural outlet from Lake Erie is through the Niagara River into Lake Ontario, which is about 326 feet lower than the level of Lake Erie. Approximately 310 feet of the difference in elevation occurs in the reach of the Niagara River extending from the head of the Cascades, upstream from

Niagara Falls, to the lower end of the Lower Rapids, six and one-half miles downstream from the falls; about half of the difference occurs in a sheer drop at the falls (see Figure 2-2).

Water is diverted from the Niagara River above the falls for power generation (details of hydro-power facilities are described in Subsection 2.3.3). A structure, extending from the Canadian shoreline to approximately the mid-point of the Niagara River, assists in the apportionment of the river's flow between the power generation intakes and the falls in accordance with the Niagara River Treaty of 1950. This structure, located 16 miles downstream of Lake Erie at a point where the river level is about nine feet lower than the level of Lake Erie, cannot be used to control the level of Lake Erie.

Water from Lake Erie also reaches Lake Ontario by way of the Welland Canal and DeCew Falls power plant tailrace (see Subsection 4.4). Water is also diverted from the Niagara River at Tonawanda, New York, through the New York State Barge Canal. This flow is returned to Lake Ontario via the Oswego River, Genesee River, Oak Orchard Creek, and Eighteen Mile Creek.

The Niagara River Treaty of 1950 provides that "water made available for power purposes by the provisions of this treaty shall be divided equally between the United States of America and Canada." Not included as a part of the water so allocated by the treaty are 5,000 cfs of the diversions into the basin through the Ogoki and Long Lac Diversion projects. The allocation to Canada of this diverted water at Niagara Falls was authorized in 1940. This diversion is utilized at the Ontario Hydro DeCew Falls plant and is part of the Welland Canal diversion mentioned in the preceding paragraph.

2.1.6 Lake Ontario and St. Lawrence River

Lake Ontario, the lowest in the Great Lakes chain, also has the smallest water surface area. Since 1958, with the completion of the control works in the St. Lawrence River for the Seaway and Power Project, the outflows from Lake Ontario have been regulated (see Figure 2-2).

From the outlet of Lake Ontario at Kingston, Ontario, to Father Point, Quebec, which marks its transition to the Gulf of St. Lawrence, the St. Lawrence River falls approximately 245 feet. Throughout the first 67 miles of its length, the river is characterized by numerous rocky islands and reefs, and is commonly known as the "Thousand Islands" reach. With the construction of the St. Lawrence Seaway and Power Project, the physical features of the St. Lawrence River further downstream were changed considerably.

Situated 105 miles downstream from Lake Ontario at Barnhart Island, New York, just west of Cornwall, Ontario, are the large Moses-Saunders Powerhouses, operated by the Power Authority of the State of New York and

Ontario Hydro respectively, which ordinarily control the St. Lawrence River flow. At the upstream end of Barnhart Island is the Long Sault Dam, which is used to pass excess flows during periods of high supplies or shut-down of the powerhouse turbines. The man-made lake formed by impounding the river behind these structures has been named Lake St. Lawrence. The fluctuations in levels of this lake, which are regulated by these impounding structures, can also be moderated by operation of the Iroquois Dam, about 27 miles upstream. Below the powerhouses, the river divides into two channels around Cornwall Island and then widens to form Lake St. Francis.

Downstream from Cornwall Island, the river lies entirely within Canada. From Lake St. Francis, the river flows to Lake St. Louis through two channels, the Beauharnois Power and Navigation Canal and the Coteau works and Cedars Hydropower developments. Situated at the lower end of the Beauharnois Canal is Hydro Quebec's Beauharnois Powerhouse. From the outlet of Lake St. Louis, the river drops through the Lachine Rapids into the La Prairie basin and thence through the short, swift-flowing section near Victoria Bridge to Montreal Harbour, a total drop of about 50 feet. In the 169 miles of river between Montreal and Quebec City, the fall is about 25 feet at low tide. The range of tide at Quebec City averages about 16 feet, but the extreme high spring tides can exceed 21 feet. The tidal effect diminishes upstream until the range is only about 1-1/2 feet maximum at Trois-Rivieres, Quebec, and 1/2 foot maximum at the upper end of Lake St. Peter which is approximately 60 miles downstream from Montreal. Very small tidal variations have been detected in Montreal Harbour. Below Quebec City, the river gradually widens into the St. Lawrence estuary and, finally the Gulf of St. Lawrence. The navigation channel between Montreal and Quebec City, referred to as the St. Lawrence Ship Channel, has an advertised depth of 35 feet at low water datum. Downstream of Quebec City, the present controlling depth is 41.0 feet LNT (Lowest Normal Tide).

2.2 Environmental Setting

2.2.1 Geography

The Great Lakes and their connecting waters occupy a drainage basin of about 297,500 square miles, of which 59 per cent is in the United States and 41 per cent in Canada. Collectively, the Great Lakes constitute the largest freshwater body in the world and serve as a vital natural resource of ever-increasing importance to both the United States and Canada. Figure 2-1 provides a map of the basin and its major component lakes and connecting waters. The more important physical features of the five Great Lakes and Lake St. Clair are summarized in Table 2-1.

The basin can be divided into three physiographic regions -- the Laurentian Uplands, the Interior Lowlands, and the Appalachian Plateau. The latter is relatively insignificant in the total basin as it intrudes only marginally on the southern shores of Lake Erie and Lake Ontario. The Laurentian Uplands encompass Lake Superior and the area north of the North

Table 2-1

PHYSICAL ASPECTS OF THE GREAT LAKES & LAKE ST. CLAIR

Lake	Water Surface(1) (mi^2)	World Standing in Area (freshwater)	Drainage Basin(1) (mi^2)	Shoreline Length(1)* (mi)	Maximum Depth(1) (ft.)	Mean Depth (ft.)	Mean Outflows(3) (cfs)	Extreme Range Fluctuation(2) (ft.)
Superior	31,700	1	81,000	2,970	1,330	487	75,000	3.8
Michigan	22,300	6	67,900	1,640	923	276	51,000	5.7
Huron	23,000	5	73,700	3,890	750	195	180,000	5.7
Erie	9,900	12	32,600	977	210	58	203,000	6.0
Ontario	7,300	14	30,740	712	802	283	238,000	6.6
St. Clair	430		5,230	389	21	10	184,000	6.4
	94,630		291,170	10,578				

[1]From Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data, "Coordinated Great Lakes Physical Data," May 1977

[2]Based upon monthly mean elevation at master gauge sites (see Table 3-4)

*Including islands and outlet rivers (except for Lake Ontario)

[3]Provided by the Coordinating Committee on Great Lakes Basic H&H Data, 1900-1978 period of record (unpublished)

Channel and the northeastern shores of Georgian Bay, Lake Huron. It is poorly drained and characterized by low-lying swamps and occasional ranges of exposed bedrock hills such as the La Cloche Mountains north of Georgian Bay. Land use is largely for timber and recreation. The Interior Lowlands include all of the remaining area in the basin except for the small area of the Appalachian Plateau in the southeast. With major deposits of glacial drift consisting of heterogeneous mixtures of sand, gravel, boulders, silts and clays occupying most of the area, drainage in the Interior Lowlands is better than that of the Laurentian Uplands. The relief of this area is flat to gently rolling. Land use in the Interior Lowlands is more intensified with agricultural, urban and industrial developments predominating.

Summaries of shoreline land use within the United States and Canada are presented in Tables 2-2 and 2-3.

2.2.2 Aquatic Resources

2.2.2.1 Fish

Over the past 100 years, fish stocks of the Great Lakes have undergone continuing and increasingly rapid changes. The predominant factors contributing to these changes have been identified as intensive and selective fishing practices, introduction or invasion of new species, and changes in the physical and chemical environment of the lakes.

Hubbs and Lagler, (1958)[8] provided the first detailed checklist of the fish fauna of the Great Lakes basin. They recorded 173 species from 29 families present in the system. Since their publication, many changes have occurred; new species have appeared while others have disappeared. Table 2-4 shows the relative distribution of the 24 families of fishes recorded to be present in each of the five Great Lakes.

The two lower lakes, Ontario and Erie, have perhaps experienced the greatest ecological upheaval within the system. Lake Ontario, which has suffered longest from intensive exploitation and environmental changes, has the lowest fish productivity of any of the five lakes and nearly all species that were abundant until the early 1900s have now become scarce. In Lake Erie nearly all the more valuable commercial and recreational species have been greatly reduced or are declining; yet this lake continues to dominate the Great Lakes commercial fish production. Less desirable species such as carp, goldfish, rainbow smelt, and sheepshead have begun to assume prominent roles in the lake's fish community. However, in recent years, the population of walleye in Lake Erie has appeared to rebound. This, together with the intensive stocking of salmon species has spurred renewed sport fishing interests.

Table 2-2

UNITED STATES SHORELINE LAND USE BY LAKE

Lake	Length mile	Inland Water	Wetland	Forest	Brushland	Grassland	Barren	Plowed	Total Urban* Residential	High Density Residential	Low Density Residential	Commercial
		PERCENT										
SUPERIOR[a]	892	2.7	8.0	62.1	4.5	1.1	5.6	0.5	15.6	1.4	14.0	0.2
MICHIGAN	1,400	0.9	5.9	35.8	8.0	5.6	1.3	5.6	36.9	7.1	25.3	4.5
HURON	580	3.7	7.5	31.6	9.6	4.1	0.0	7.4	36.2	9.0	27.0	0.2
ST. CLAIR[b]	117	1.0	9.8	4.2	4.4	1.2	0.0	5.8	73.6	24.4	22.5	26.7
ERIE	431	0.4	6.7	10.6	9.0	4.8	1.0	9.7	57.8	23.4	21.7	12.7
ONTARIO[c]	336	3.3	2.8	24.4	14.0	7.8	0.1	5.2	42.4	5.7	36.3	0.4
GREAT LAKES SYSTEM**	3,756	2.0	6.8	28.1	8.2	4.1	1.3	5.7	43.8	11.8	24.5	7.5

a - Includes St. Marys River

b - Includes St. Clair River, Lake St. Clair, and Detroit River

c - Includes Niagara River

* - Total Urban Residential is the total of High Density Residential, Low Density Residential, and Commercial Classes.

** - Excluding St. Lawrence River Basin

Source: Great Lakes Basin Commission, Summary of Existing and Projected Land Use Information for the Great Lakes Coastal Counties, Contract #W74 RDV 78290 005 for U.S. Army Corps of Engineers, November 1978.

Table 2-3

CANADIAN SHORELINE LAND USE BY LAKE
(Miles)

Type	Superior[1]	Huron[1]	St. Clair[1]	Erie[1]	L. Ontario & St. Lawrence R.[1] To Cornwall, Ont.	St. Lawrence R.[2] Cornwall-Trois-Rivieres, Que.
Residential	12	244	35	164	269	320
Commercial	106	169	4	7	14	70*
Industrial	-	-	.6	.6	20	30
Agricultural	-	2,169	21	89	327	210
Forest	1,250	-	12	56	90	250
Other	-	25	4	19	24	-
Recreation (private)	131	525	14	-	1	-
Recreation (public)	-	-	29	62	311	-

[1]SOURCE: Canada - Ontario Great Lakes Shore Damage Survey

[2]SOURCE: The St. Lawrence Study Committee

*Figure is for Roads

Table 2-4

FAMILIES OF FISH COMMON TO THE GREAT LAKES

Family		Lake				
Common Name	Scientific Name	Ontario	Erie	Michigan	Huron	Superior
Lamprey	Petromyzontidae	4	3	4	4	3
Sturgeon	Acipenseridae	1	1	1	1	1
Gar	Lepisosteidae	1	2	2	2	
Bowfin	Amiidae	1	1	1	1	
Herring	Clupeidae	3	1		1	
Salmon	Salmonidae	10	4	13	12	12
Mooneye	Hiodontidae	1				
Mudminnow	Umbridae	1	1	1	1	1
Pike	Esocidae	4	3	3	3	2
Minnow	Cyprinidae	33	33	31	24	20
Sucker	Catostomidae	9	14	13	8	5
Catfish	Ictaluridae	7	8	6	6	3
Eel	Anguillidae	1	1			
Livebearer	Poeciliidae	1	2	3	1	
Cod	Gadidae	1	1	1	1	1
Stickleback	Gasterosteidae	3	1	2	2	2
Trout-perch	Percopsidae	1	1	1	1	1
Pirate perch	Aphredoderidae	1	1	1		
Temperate bass	Percichthyidae	1	1	1	1	1
Sunfish	Centrarchidae	9	11	11	10	4
Perch	Percidae	12	17	13	14	7
Drum	Sciaenidae	1	1	1	1	
Sculpin	Cottidae	4	4	4	4	4
Silverside	Atherinidae	1	1	1	1	
Families		24	23	21	21	15
Species		111	113	114	99	67

Numbers denote numbers of species found in each lake
Modified from RYDER, (1972)[16]

Some of the more spectacular declines in Great Lakes fish stocks were the elimination of the Atlantic salmon in Lake Ontario before the turn of this century, the intentional overfishing of the lake sturgeon, the collapse of the whitefish population in the Lake St. Clair area and in Green Bay, the disappearance of lake trout stocks from Lakes Ontario, Michigan, Huron, and Superior in the 1950s and 1960s, the depletion of lake herring stocks in Lakes Ontario and Erie and in Saginaw Bay and Green Bay, and the elimination of some populations of chub in Lakes Huron and Michigan.

Table 2-5, constructed from data presented by Baldwin and Saalfeld, (1962 with 1970 addenda)(1), is intended to provide a chronicle of the changes that have occurred in the commercial fisheries of each of the five Great Lakes. They also show the relative contribution to the total Great Lakes catch during the selected years.

While some stocks declined, others flourished, particularly those of the less desirable foreign species such as the alewife, sea lamprey, rainbow smelt, and white perch.

Until recent years, Great Lakes research and the development of fishery resources have been directed, to a large degree, towards commercial species, particularly those found in the mid-to-deep water portions of the open lakes. However, in order to direct sport fishing activity away from overused inland waters, researchers and managers gave more attention to the productive nearshore sport fishery of the Great Lakes and the introduction of intensive stocking programs, particularly those of Pacific salmon, were spectacularly successful.

Several of the desirable introductions that have had a profound effect on the Great Lakes sport fishery include Pacific salmon, particularly coho, chinook and kokanee; splake; and brown, brook, steelhead, and lake trout. The returns of a late 1960s stocking program by the State of Michigan have been remarkable. In the State's Lake Michigan waters alone, 500,000 coho, 275,000 steelhead, 229,000 lake trout, and 170,000 chinook salmon were caught in 1970. The economic importance to a local area of such a resource is enormous. Similar successful recoveries of planted trout and salmon have been recorded in Lakes Ontario, Erie, Huron, and Superior.

It is generally recognized that statistics for the Great Lakes sport fishery, with few exceptions, are not as reliable as or comparable to those collected for the commercial fishery, but it is also well known that in some locations the harvest of certain species by anglers is significant. For example, a limited creel census conducted in the Bay of Quinte, Lake Ontario in the late 1950s-early 1960s, indicated that sport fishermen recorded about 32 percent of the walleye catch compared to 68 percent by commercial fishermen. The total annual walleye harvest in the bay ranged between 53,000 and 77,000 fish per year during the five-year census. The walleye harvest also provided in excess of 100,000 man-hours of recreation for sportsmen each year.

Table 2-5

ORDER OF YIELD OF PRINCIPAL[1] COMMERCIAL SPECIES CAUGHT IN THE GREAT LAKES IN SELECTED YEARS FROM 1908 TO 1977

LAKE ONTARIO

Order of Yield	1908	1920	1930	1940	1950	1960	1970	1977
1	L.herring*(C)	L.whitefish*(C)	L.herring[2]*(C)	L.herring*(C)	Catfish	L.whitefish	Y.perch*	Y.perch
2	L.whitefish	L.herring*	L.whitefish	Carp	L.whitefish	Bullheads	W.perch	W.perch
3	Catfish	L.trout	L.trout	L.whitefish		Carp	Carp	Bullheads
4	Walleye(B)	N.pike					Bullheads	American Eel
5	N.pike							
Total[3] Yield	4,016	5,318	4,703	4,381	2,408	2,234	3,238	2,668

LAKE ERIE

Order of Yield	1908	1920	1930	1940	1950	1960	1970	1977
1	L.herring**	L.herring***	Bl.pike**	Bl.pike*	Bl.pike**	Y.perch**	Y.perch***[2]	Smelt***[2]
2	Carp*	Bl.pike*	Y.perch*	L.whitefish*	Walleye*	Smelt**	Smelt*	Y.perch**
3	Bl.pike*	Carp*	Sheepsh.*	Y.perch*	Y.perch*	Sheepsh.*	Carp*	Carp*
4	N.Pike*	Sauger*	L.whitefish*	Walleye*	Sheepsh.*	Wh.bass*	Sheepsh.*[1]	Sheepsh.*
5	Walleye*	Y.perch*	Carp*	Sheepsh.*	L.whitefish*	Carp*	Wh.bass*	Wh.bass*
Total[3] Yield	53,212	49,044	42,264	32,711	40,848	50,477	41,320	45,538

LAKE HURON

Order of Yield	1908	1920	1930	1940	1950	1960	1970	1977
1	L.herring(C)*	L.trout*	L.herring*	L.trout*	L.whitefish*	Chubs*	Carp*	L.whitefish*
2	L.trout*	L.herring*	L.trout*	L.herring*	L.herring*	Carp*	L.whitefish*	Carp
3	L.whitefish*	L.whitefish*	L.whitefish*	Walleye*	Carp*	Y.perch*	Y.Perch	Y.perch
4	Suckers*	Suckers*	Suckers*	Suckers*	Suckers	L.whitefish*	Suckers	Chubs
5	Walleye*	Carp*	Walleye*	L.whitefish*	Y.perch	Suckers	Ch.catfish	Ch.catfish
Total[3] Yield	20,718	17,865	22,209	14,674	9,835	10,251	4,536	5,955

LAKE MICHIGAN

Order of Yield	1908	1920	1930	1940	1950	1960	1970	1977
1	L.herring[2](C)**	L.trout*	L.herring*	L.trout*	Chubs*	Chubs[2]**	Alewife[2]***	Alewife[2]***
2	L.trout*	L.herring*	L.trout*	Smelt*	L.herring*	Y.perch*	Chubs*	L.whitefish*
3	Y.perch*	Chubs*	L.whitefish*	L.herring*	Smelt*	Smelt*	Coho*	Y.perch
4	L.whitefish*	Y.perch*	Chubs*	Y.perch*	L.whitefish*	Alewife*	Smelt*	Smelt
5	Suckers*	L.whitefish	Suckers*	Suckers*	Y.perch*	Carp*	Carp*	Carp
Total[3] Yield	47,356	19,999	26,962	22,601	27,078	24,311	53,090	50,473

LAKE SUPERIOR

Order of Yield	1908	1920	1930	1940	1950	1960	1970	1977
1	L.herring*	L.herring[2]*	L.herring[2]**	L.herring[2]**	L.herring[2]*	L.herring[2]**	L.herring[2]*	Smelt*
2	L.trout*	L.trout*	L.trout*	L.trout*	L.trout*	Chubs*	Smelt*	L.herring*
3	L.whitefish*	L.whitefish	L.whitefish	L.whitefish*	L.whitefish*	Smelt	Chubs*	Chubs*
4	Chubs		Chubs	Chubs		L.trout	L.whitefish	L.whitefish
5	Suckers					L.whitefish	L.trout	L.trout
Total[3] Yield	12,487	12,622	19,627	23,991	15,239	16,599	8,391	8,386

[1]more than 250,000 lbs.
[2]landings exceeded more than 50 percent of total for year
[3]thousands of pounds
*catch more than 1 million lbs.
**catch more than 10 million lbs.
***catch more than 20 million lbs.

Catfish includes Bullheads, Ch.catfish does not
(C)Lake Herring includes Chubs
(B)Walleye include Blue Pike

Lake St. Clair, unlike most of the other water bodies in the Great Lakes system, has a relatively good record of sportsman use and harvest. The Michigan Department of Natural Resources has estimated the sport catch of yellow perch, from U.S. Lake St. Clair waters alone, during a five-month period, to be almost 1,500,000 fish and, during an aerial census, as many as 600 fishing boats were counted in a single day.

Lake Huron, before the collapse of the lake trout stocks in the 1950s, supported a significant lake trout sports fishery, particularly in southwestern Georgian Bay and the offshore waters north of Saginaw Bay. Both area fisheries supported charter boat services which contributed considerably to the local economies. There is still a substantial inshore fishery for yellow perch, walleye, smallmouth bass, and northern pike in Lake Huron. The estimated recreational catch of yellow perch in Saginaw Bay during 1975, for example, was 43 tons, about one third of the total commercial perch catch for that year.

It has been noted how the sport fishery of Lake Michigan has spectacularly rebounded with the successful introduction of Pacific salmon and several species of trout. A study of walleye in northern Green Bay, Lake Michigan, in the 1950s demonstrates the economic importance of a single species to a local area. A single year-class of walleye, produced in 1943, so enchanced the total fishery that extensive resort facilities were built to accommodate the greatly increased numbers of anglers.

Lake Superior, like Lake Huron, has historically supported a commercial sport fishing charter service. In the 1940s and 1950s virtually every U.S. port on Lake Superior had commercial outfitters supplying accommodations and boats to sportsmen wanting to troll for lake trout. In 1950, it was estimated that 47 part-time and 10 full-time charter boats were available for hire in Canadian ports. This local but significant industry collapsed in the 1950s with the collapse of the lake trout stocks.

Although drastic changes have occurred during the past 100 years, the fishery of the Great Lakes system, both commercial and recreational, remains an important contributor to the economy of the region.

2.2.2.2 Wetlands and Wildlife

Most reaches of the Great Lakes shorelines are too harsh to support many plants or animals.(6) These areas are under continuous assault from high wave energy which creates barren substrate to depths of 10 to 16 feet along the open shoreline of all the Great Lakes. However, throughout the coastline, there exist numerous small pockets of naturally protected habitats. These areas are limited to seven percent of the total shoreline; thus, the importance and value of such unique shoreline environments is tremendously significant for this aquatic system. Sites of this type are considered the "most valuable wildlife habitat found on the Great Lakes."(10)

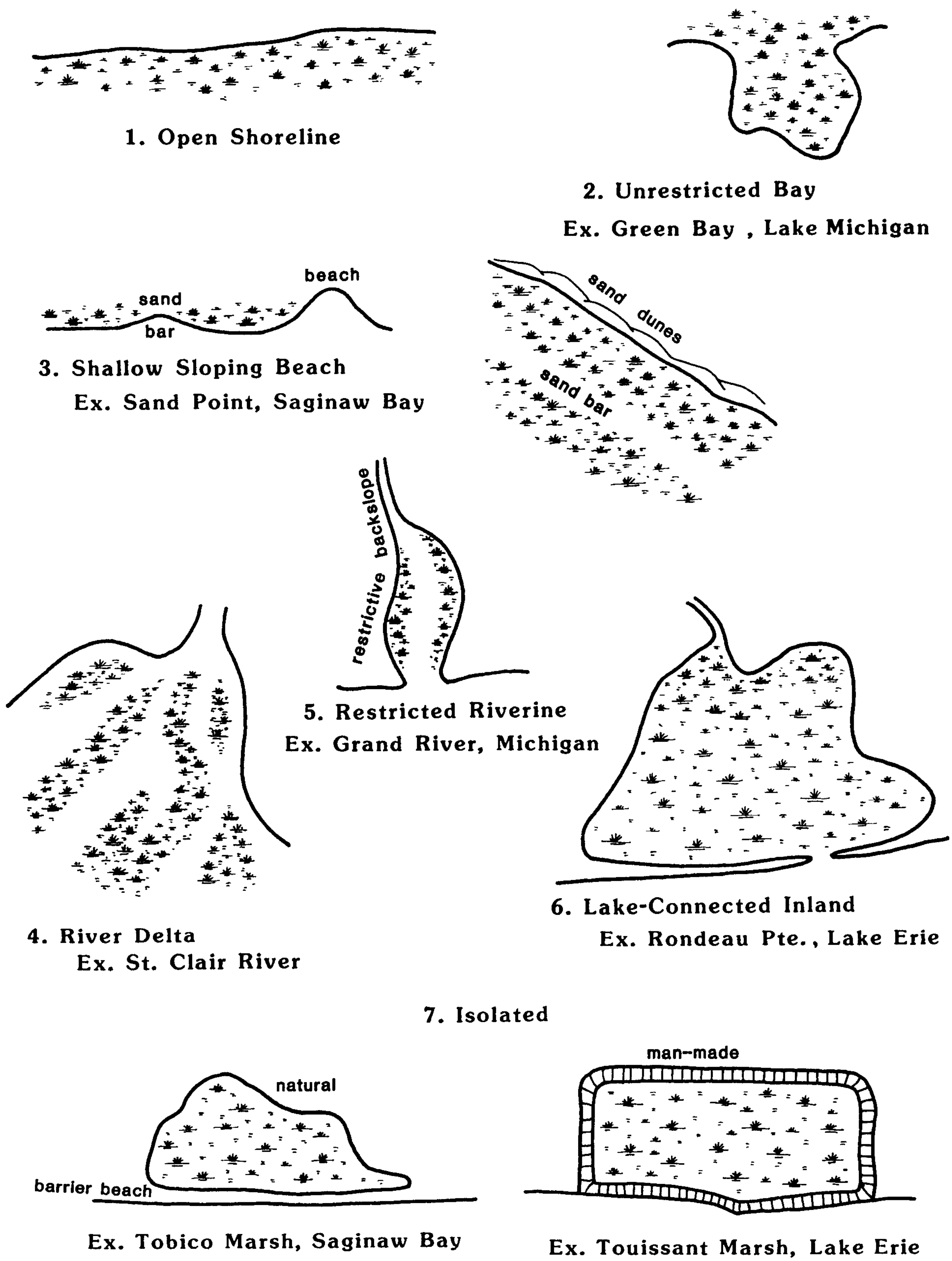
Throughout the Great Lakes, wetlands occupy a variety of places; along open shores, in back-barrier lagoons, river deltas, river-bay mouths, isolated coves, and shallow sloping beaches. All have a number of factors in common, i.e., low wave energies, gradual bathymetric slopes, shallow water, and suitable substrate sediments. Figure 2-3 depicts different wetland morphologies. None of the lakes has a single, specific wetland type associated with it; however, a uniform wetland type may occupy several miles of a reach, or a number of types may be found in close proximity to one another.

Major wetland complexes exist throughout the Great Lakes and serve valuable functions. The main locations are the Bay of Quinte, Lake Ontario; Long Point, Rondeau Point, and the western end of Lake Erie; Lake St. Clair; Saginaw Bay, Lake Huron; and Green Bay, Lake Michigan. Other small pockets of wetlands are scattered along the shoreline and are far too numerous to list. These areas support diverse lower forms of flora and fauna which are critical to survival of higher forms of fish and wildlife in the Great Lakes.

The marshes, swamps, and bogs in this region, while not as extensive as earlier years, still provide good wildlife habitat. Approximately 170,255 acres on the U.S. side and 98,435 acres on the Canadian shores were classified good wildlife habitat in 1973[11]. Waterfowl, including ducks, geese and shorebirds, require wetlands for breeding, feeding, rearing and migration areas. Saginaw Bay, Lake St. Clair and the western end of Lake Erie, located at a junction of two major flyways in North America, are well known concentration areas for migrating waterfowl. The migrants stop at these locations to rest and feed on their yearly travels. Tremendous numbers of birds congregate due to the protected environment and availability of food. Key foods include wild celery (Vallisneria sp.), smartweeds (Polygonum sp.) water plantains (Alismaceae), grasses (Gramineae), sedges (Cyperaceae), and many of the submerged aquatics that provide habitat for invertebrates.

Fish are also heavily reliant on wetlands. Many important gamefish, which include largemouth bass, northern pike and muskellunge, require wetlands for survival. Some species are even dependent on specialized conditions. For example, northern pike (Esox lucius) are dependent on early spring flooding of sedge or shrub meadows for spawning. Adults feed and rest in floating, submerged and emergent vegetation throughout the warmer months. Juvenile fish rely on heavy vegetation for cover and also feed on the invertebrate populations that inhabit the submerged vegetation.

A variety of mammals are dependent upon or utilize wetlands. The principal mammal found in the Great Lakes wetlands is the muskrat. These animals prefer to feed on cattails, bullrush, and blue-joint grass,[3] but numerous other kinds of plants are eaten as well. Muskrat dens are constructed mostly of cattails, but may also be dug in banks, hillsides, or dikes, should preferred conditions not exist.



Wetland Morphologies

Figure 2-3

Other mammals frequenting wetland areas are raccoons, white tailed deer, weasels, beaver, red fox, and mink. Although not continuous users, these animals may feed, rest and breed within these areas. Some animals show a definite preference for wetland vegetation and thus may feed in these areas frequently.

Wetlands and the associated flora and fauna are important for some commercial ventures. Hunting, fishing and trapping are dependent on the quality, size and availability of these areas. A recent study done for the Michigan Department of Natural Resources(14) reviews the functions served by wetlands and attempts to quantify the economic value of these areas. This study of the fish, wildlife, and recreational resource values of Michigan's 105,855 acres of coastal wetlands, established a unit acreage value of approximately $490.00 or a total value of $51.8 million (Table 2-6). These values were calculated using the economic value of the fish, wildlife, and nonconsumptive recreational resources as determined from estimates of sport and commercial harvests, average annual expenditures by participants engaged in fishing and hunting, and on value of recreational days.

Table 2-6

FISH, WILDLIFE AND RECREATIONAL VALUE OF MICHIGAN'S COASTAL WETLANDS, 1978(14)

Sport Fishing	$286.00/acre/year
Nonconsumptive Recreation	$138.24
Waterfowl Hunting	$ 31.23
Trapping for Furbearers	$ 30.44
Commercial Fishing	$ 3.78
Total	$489.69 x 105,855 = $51.8 million

2.2.2.3 Endangered and Threatened Species

Considerable concern has arisen in the last few years over endangered and threatened species. An organism that is in danger of extinction throughout all or a significant portion of its range is considered endangered, while one that is likely to become endangered within the foreseeable future throughout all or a significant portion of its range is considered threatened. The Great Lakes coastlines provide habitat for endangered and threatened species that are distinctive from any others on earth.

Both Canada and the United States at the federal and state or provincial levels, have formalized species lists and laws protecting these organisms. Table 2-7 presents a list of laws and references on species of concern in the Great Lakes region. These organisms and their habitat are to receive basic consideration in all projects according to these regulations. Table 2-8 presents a list of endangered and threatened species in or near the Great Lakes.

Table 2-7

REFERENCES AND LAWS ON ENDANGERED AND THREATENED SPECIES FOR THE GREAT LAKES REGION

NATIONAL

Endangered and Threatened Species Act of 1973 plus Amendments of 1978 (16 United States Code 1531-1543; 875 Stat. 884)

"List of Endangered and Threatened Wildlife and Plants" produced under the Endangered Species Act available in Title 50 Code of Federal Regulations (CFR) Part 17.

Endangered Species Act of 1971 (Canada)

PROVINCIAL

"The Rare Vascular Plants of Ontario" G.W. Argus and D. J. White, National Museum of Natural Sciences, June 1977.

STATE

"Endangered, Extirpated, and Extinct Wildlife of New York State" New York Department of Environmental Conservation. May 1979.

"Pennsylvania's Endangered Fish, Reptiles and Amphibians" Pennsylvania Fish Commission, Harrisburg, PA.

"Endangered Wild Animals in Ohio," Ohio Department of Natural Resources, Division of Wildlife, Publication 316. May 1976.

"Michigan's Endangered and Threatened Species Program," Michigan Department of Natural Resources. January 1980.

"Non-game and Endangered Species Conservation, A Preliminary Report, 1978" Indiana Department of Natural Resources.

"Endangered Animals in Wisconsin", Wisconsin Department of Natural Resources, October 1975 (revised May 1978).

Table 2-8

SELECTED ENDANGERED AND THREATENED SPECIES THAT INHABIT OR FREQUENT THE COASTAL AREAS OF THE GREAT LAKES

COMMON NAME	SCIENTIFIC NAME
MAMMALS	
Gray Wolf	Canis lupus
Indiana Bat	Myotis sodalis
Badger	Taxidea taxus
BIRDS	
American Peregrine Falcon	Falco peregrinus anatum
Arctic Peregrine Falcon	Falco peregrinus tundrius
Piping Plover	Charadrius melodus
Bald Eagle	Haliaeetus leucocephalus
Common Tern	Sterna hirundo
Osprey	Pandion haliaetus
Double-Crested Cormorant	Phalacrocorax auritus
Marsh Hawk	Circus cyaneus
Caspian tern	Hydroprogne caspia
REPTILES	
Illinois Mud Turtle	Kinosternon flavescens spooneri
Northern Copperbelly	Natrix erythrogaster neglecta
FISHES	
Northern Madom	Noturns stigmosus
Silver Shiner	Notropis photogenis
Shortnose Cisco	Coregonus reighardi
Blue Pike	Stizostedion vitreum glaucum
Short Jaw Cisco	Coregonus zenithicus
Long Jaw Cisco	Coregonus alpenae
Lake Sturgeon	Acipenser fulvescens
Striped Shiner	Notropis crysocepalus
Cisco or Lake Herring	Coregonus artedii
Kiyi	Coregonus kiyi
Bloater	Coregonus hoyi
MUSSELS	
White Cat's Paw Pearly Mussel	Epioblasma sulcata delicata
No Common Name Listed	Simpsoniconcha ambigua
" " " "	Obovaria leibii
" " " "	Pleurobema clava
" " " "	Elliptio complanatus
" " " "	Cyclonaias tuberculata

Table 2-8 (Continued)

MUSSELS (Cont.)

No Common Name Listed	*Anodonta subgibbosa*
" " " "	*Actinonaias ellipsiformis*
" " " "	*Lampsilis fasciola*
" " " "	*Dysnomia triquetra*

SNAILS

No Common Name Listed	*Lymnaea megasoma*
" " " "	*Pomatiopis cincinnatiensis*

PLANTS

American Lotus	*Nelumbo lutea*
Pitcher's Thistle	*Cirsium pitcheri*
Dwarf Lake Iris	*Iris lacustris*
Houghton's Goldenrod	*Solidago houghtonii*
Lake Huron Tansy	*Tanacetum huronense*
Monkey-flower	*Mimulus glabratus* var. *michiganensis*
Thickspike Wheatgrass	*Agropyron dasystachyum*
Butterwort	*Pinguicula vulgaris*
Swamp Rose-mallow	*Hibiscus palustris*

The variety of shoreline habitat on the Great Lakes affords a diversity of niches. Conditions can range from completely submerged to severely arid. Organisms may require the submerged conditions of the littoral zone, saturated soil conditions of wetland areas, or the more arid conditions encountered in dunes or bluffs. Beaman[2] reports that 38 percent of the extinct, endangered and threatened species in Michigan presently occupy, or have occupied, aquatic or wetland habitat. These same habitat are common throughout the region, so similar high percentages can be expected in other locations as well.

Although coastal habitat accommodate severe natural disturbances, they are unusually sensitive to unnatural changes. Man-made changes in the shoreline environment, such as filling or dredging, interfere with natural habitat dynamics. Natural changes, which include erosion by large waves and flooding, create wide fluctuations in available habitat. Human interference with these fluctuating conditions could impact with a species in its most vulnerable state, eventually leading to extinction or severe limitation.

2.2.3 Coastal Zone

2.2.3.1 Shoreline Characteristics

The physical characteristics of the shores of the Great Lakes are the result of development of the Great Lakes region since the recession of the last ice sheet. They range from high bluffs of clay and sand, shale and bed rock, through lower rocky shores and sandy beaches, to low, marshy clay flats. Except where bedrock is exposed or protective works have been constructed, the glacial overburden comprising the shores of the Great Lakes is still vulnerable to shore erosion. The principal causes of erosion and flooding problems are the forces of nature and the characteristics of the shoreline subjected to these forces.

The first major cause of the problems - the forces of nature - involves storm-driven wave action, lake level fluctuations, frost and ice action, underground water seepage and surface water runoff. Major storms cause the largest changes to shore morphology. The direction, magnitude, and duration of storms, together with the fetch length, determine wave heights and littoral currents. Persistent storms can build waves up to great heights and when superimposed upon high lake levels contribute to major variations in wave intensity.

When high lake levels are coincident with the other forces of nature cited here, they can greatly magnify total effects. Because of the large size of the Great Lakes and the limited amount of water their outflow rivers can discharge, extremes of high or low water levels and flows persist for a considerable time after the factors that caused them have changed.

Wave action works directly on a beach or at the toe of a bluff, eroding clay, silt, sand and gravel. This erosion is increased when lake levels rise because the beaches are narrower or submerged, and the waves are able to attack the unprotected toe of the banks or bluffs directly. Thus, a wide beach is the best protection the upland shore can have from wave attack.

Seepage often comes through sandy layers which overlie an impervious clay layer in glacial till bluffs. When groundwater seeps out of exposed bluffs of unstable or loose material, it causes slumping and further weakens the material. This often results in large slides. Sometimes man-made drainage works interfere with groundwater. Overland runoff carries with it large amounts of erodible material, particularly where there are barren, steeply-sloping bluffs.

One of the most severe threats to the shore is erosion by frost and ice. In certain of the finely-grained silty soils along the lakes, alternate freezing and thawing can weaken the soil and cause it to slide. Frost and ice formation in fissures of clays, glacial tills, or shale bluffs may contribute to their erosion. Shore ice is another cause of damage when broken up and driven onto the beaches by on-shore storms. Lake bottom material may be scoured or structures damaged. However, shore ice may also be of benefit as it can protect the shore from erosion by winter storms.

A second major factor influencing erosion lies in the characteristics of the shoreline upon which the forces of nature impact. The principal characteristics here include the orientation, resiliency, and man's use of the shoreline.

An unfavorable orientation can magnify lake levels and wave intensity. Winds, particularly of storm velocity, and sharp gradients in barometric pressures over short distances can cause wide fluctuations in lake levels. When short-period fluctuations are superimposed on above-average levels, they may cause unusually high water levels. High storm levels at one end of a lake are accompanied by lower levels at the opposite end. Pronounced fluctuations from these causes are also experienced in bays and other shallow portions of each lake. Lake Erie is particularly vulnerable to these phenomena.

The durability of the coastline to water dynamics depends upon the material of which the shorefront is composed. The rocky shores of Lake Superior, the sandy beaches of Lake Michigan, and the silty-clay bluffs at Scarborough (Ontario) on Lake Ontario, for example, show a progressively diminishing resiliency in their ability to withstand wave forces.

Beaches are energy dissipators. Their efficiency in this role is greatly influenced by their profile. The nearer deep water is to the shore, the closer large waves can approach before their energy begins to dissipate because of bottom drag and wave breakup. The flatter the gradient, both offshore and on the beach "run up" area, the longer and more gradual is this dissipation. A narrow, steep beach will be subject to much greater wave forces than a flatter beach. An offshore bar, breakwater or island will dissipate waves, affording protection within the areas they shelter.

Man's use of the shoreline is more concentrated in some areas than in others. A most significant aspect of shoreline use is the amount of shore occupied by recreational, residential, commercial, and industrial developments (urban serving). For example, in the southern part of Lake Michigan 86 percent of the shoreline is in these shoreline classification categories. Similar occupancy percentages exist in the vicinity of Detroit and on the shoreline of Lake Erie. Even in the relatively uninhabited shores of Lake Superior, 30 percent of the shoreline is dedicated to urban uses. During the last 30 years, forestry and agricultural uses of shoreline lands have declined as a result of the demands of an expanding urban population.

Tables 2-9 and 2-10 summarize the shoreline characteristics. An analysis of the data suggests the following: 33 percent of the total shoreline use is residential; ten percent is recreational (public); and seven percent commercial-industrial and institutional (public buildings); the remaining 50 percent is devoted to agriculture and forestry or remains undeveloped. Only 17 percent of the Great Lakes shoreline is publicly owned; the remainder (83 percent) is private. One third of the Great Lakes shoreline is subject to significant erosion. Over the last 125 years, the average annual erosion rate in many locations has varied from one to five feet. About 215 miles of shoreline is subject to critical erosion; i.e., where severe loss of land has created economic hardship, damage to public utilities or otherwise endangered the public well-being.

2.2.3.2 Areas Subject to Erosion

The U.S. Lake Superior shore has local erosion problem areas at Whitefish Bay, Ontonagon and Keweenaw Waterway, Michigan, and Ashland, Wisconsin. The sandy bluffs of the Whitefish Bay area at the east end of Lake Superior, and the red clay bluffs at the southwestern end of the lake sustain severe erosion as a result of wave action from high lake levels. Little erosion damage occurs to the Canadian shoreline of Lake Superior because of its generally high, rocky nature.

The U.S. shoreline of Lake Huron south of Port Austin, Michigan, as well as the southern portion of the Canadian shoreline are subject to erosion.

Around Lake Michigan, serious erosion occurs in a number of localities as follows: the Wisconsin shore, in the vicinity of Two Rivers, Manitowoc, Racine and Kenosha; the Illinois shore; the Indiana shore; and the entire east side of the Michigan shore.

Serious erosion occurs along the entire Canadian shoreline of Lake Erie, except at the east end where rock outcroppings occur near the

Table 2-9

THE GREAT LAKES SHORELINE: DESCRIPTION, OWNERSHIP AND USE, 1970

Great Lakes Shoreline	United States (a) Total Miles	Canada (b) Total Miles
1. PHYSICAL CHARACTERISTICS		
With a beach zone	2,107	5,306
Without a beach zone	1,572	981
Total	3,679	6,287
2. USE		
Residential	1,216	1,263
Commercial	189	329
Agricultural and Undeveloped	633	695
Forest	1,159	3,396
Recreation	365	357
Public Buildings & Related Lands	60	99
Fish and Wildlife Wetlands	57	148
Total	3,679	6,287
3. OWNERSHIP		
Federal	133	374
Non-Federal Public	517	2,378
Private	3,029	3,535
Total	3,679	6,287
4. PROBLEM-IDENTIFICATION		
Non-Eroding	1,704	839
Significant Erosion		
Critical	214	320
Non-critical	1,046	4,907
Subject to Flooding	335	72
Protected	380	149
Total	3,679	6,287
5. TOTAL SHORELINE MILEAGE	3,679	6,287

(a) Source: Department of the Army, Corps of Engineers, North Central Division, Great Lakes Regional Inventory Report National Shoreline Study, August 1971; does not include islands and connecting channels.

(b) Source: 1966 Field Surveys, Department of Public Works, Canada, includes Canadian national reach to Trois-Rivieres.

Table 2-10

COORDINATED ELEMENTS OF GREAT LAKES SHORELINE LENGTHS

	Shoreline Length Components in Miles			
	In Canada		In United States	
	Mainland	Islands	Mainland	Islands
Lake Superior	866	615	863	382
St. Marys River	66	63	29	89
Lake Michigan	0	0	1,400	238
Lake Huron	1,270	1,720	580	257
St. Clair River	30	5	28	0
Lake St. Clair	71	43	59	84
Detroit River	30	33	30	39
Lake Erie	368	29	431	43
Niagara River	33	3	36	34
Lake Ontario	334	50	300	28
St. Lawrence River				
Above Iroquois Dam	103	157	106	109
Above Power Dam	150	188	151	164
TOTALS	3,321	2,906	4,013	1,467

To obtain a coordinated length, add the tabulated values of the desired combination of components and round the sum three significant digits. For example: The total shoreline length of the Lake Huron mainland and islands is 580 + 257 + 1,270 + 1,720 = 3,827, which when rounded gives 3,830 miles.

From Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data, "Coordinated Great Lakes Physical Data," May 1977.

water line. Along the U.S. shore of Lake Erie serious erosion problems exist; particularly the area from the Michigan-Ohio boundary to Marblehead, Ohio; in the vicinity of Huron and Cleveland, Ohio and along the Pennsylvania shoreline from the Ohio border up to and including the Presque Isle Peninsula. Because of the stability of the high shale bluffs, erosion and flooding problems along New York's Erie coast are few.

The U.S. shore of Lake Ontario, in the vicinity of Rochester, New York is subject to serious erosion with more moderate but similar problems occurring from the mouth of the Niagara River to the vicinity of Oswego, New York. The Canadian shoreline and the St. Lawrence River below Cornwall, Ontario also experience severe erosion damage.

2.2.3.3 Areas Subject to Inundation

Local inundation along the shores of the Great Lakes is confined to low-lying areas or to the lower reaches of tributary streams which are affected by backwater from high lake levels.

The Lake Superior shoreline in the United States has local flood problem areas at Duluth, Minnesota; Superior and Ashland, Wisconsin; and several smaller communities. The Canadian shore has rugged, rocky bluffs or cliffs and sustains only minor damages from flooding.

Principal areas subject to inundation on Lake Michigan are located along the shore of Green Bay and at Milwaukee, Wisconsin, on the west side of the lake. Numerous sites contiguous to the east shore are subject to flooding also; however, most of these areas are on lakes inland from the Lake Michigan shoreline proper but are connected to it by rivers or channels.

On Lake Huron, the Saginaw Bay area in Michigan is the only reach subject to extensive flooding, although there are other smaller scattered areas affected adversely by inundation during periods of high water. The Canadian shore of Lake Huron has beaches of varying widths backed by bluffs in the southern portion and the northern portion is predominantly bedrock with sand beaches occuring in scattered locations. Therefore, these areas experience only minor damage from flooding.

Most of the shore of Lake St. Clair, in both the United States and Canada, is subject to inundation at high lake levels.

The western shore of Lake Erie, extending from the mouth of the Detroit River to Toledo, Ohio, and the south shore, extending about 40 miles east from Toledo, are principally low-lying land with an elevation only slightly above average lake level. Other flood-prone areas in the United States exist along the shore of Sandusky Bay and the mouth of the Chagrin River in Ohio. The Canadian shoreline of Lake Erie has bluffs fronted by marginal sand beaches except at three points: Point Pelee, Point-aux-Pins and Long Point, Ontario, which sustain flooding damage. In the eastern end of the lake, flood problems are minor because bedrock is near water level and the shoreline is irregular, with bay beaches and sand dunes fronting a low clay plain.

The principal areas subject to flooding along the U.S. shore of Lake Ontario are located in the vicintiy of Rochester and Sodus Bay, New York. The more extensive of these two areas extends from Irondequoit Bay, which is five miles east of Rochester, to Wautoma Beach, about 13 miles west of Rochester, New York. The major portion of the Canadian shoreline of Lake Ontario consists of narrow, sand and gravel beaches at the toe of clay or rock bluffs which are not subject to inundation except at Burlington Bay, Presque Isle Peninsula, and Prince Edward and Frontenac Counties, where wide, long, sand beaches are located.

The shoreline of the international reach of the St. Lawrence River consists mainly of narrow, rocky beaches backed by low-lying river bank topography with few flooding problems. The Canadian reach of the river, as far as Trois-Rivieres, Quebec, has many low-lying areas subject to flooding.

2.2.4 Water Quality

The large concentrations of people, industry and agriculture in the Great Lakes basin have created water quality problems which urgently require U.S.-Canadian solutions. Programs to reduce pollution and improve water quality in the Great Lakes are difficult to design and implement because the lakes are extremely large and complex, receiving pollutants from many different sources. The Great Lakes basin also contains many different governmental jurisdictions. Because the Great Lakes constitute a large part of the international border between the United States and Canada, the IJC has become the mechanism for cooperation between the two countries in matters relating to Great Lakes water quality. The IJC's water quality responsibilities in the Great Lakes stem from the 1972 Great Lakes Water Quality Agreement. A new revised agreement was signed on November 22, 1978 which reaffirms both countries' commitment to restore and enhance the water quality of the Great Lakes.

The IJC has identified the current major water quality problems in the Great Lakes to be persistent toxic chemicals, high phosphorus inputs, contributions from airborne pollutants, and disposal of municipal and hazardous wastes. Other concerns include wastes from watercraft, runoff from urban and rural lands, fertilizers and pesticides, disposal of dredged material and thermal discharges.

The coastal waters of the Great Lakes generally exhibit good water quality. However, some localized areas are degraded due to tributary or point sources of pollutants such as nutrients, bacteria, or suspended solids.

2.2.4.1 Lake Superior

The quality of the open waters of Lake Superior generally exceeds that prescribed in the water quality objectives stated in the Water Quality

Agreement of 1978 between the United States and Canada. Degraded water quality does exist in some near-shore areas as a result of point source discharges, tributary inflows and erosion. The major problem areas are Duluth-Superior Harbor, Silver Bay, Thunder Bay, and near the erodible, red-clay bluffs along the southern shore of the lake.

2.2.4.2 Lake Huron

Lake Huron has shown recent improvements (i.e., reductions) in phosphorus loading. The waters in the main body of the lake and Georgian Bay are of good quality, generally meeting the objectives of the 1978 Water Quality Agreement. However, Saginaw Bay exhibits high concentrations of nutrients, coliform bacteria, suspended solids, PCBs, zinc, and biochemical oxygen demand (BOD) originating from the Saginaw River system. Although the general trend is toward water quality improvement, increased pollution and industrial activity in the basin could aggravate the condition of the bay if remedial programs do not keep pace with growth.

2.2.4.3 Lake Michigan

Intensive studies conducted during 1976 and 1977 have determined that Lake Michigan is still in an oligotrophic state (IJC Report, 1978).[12] Declines in total phosphorus concentrations were noted in the southern basin. Three areas identified as having significant water quality problems are Green Bay, Milwaukee Harbor, and the Indiana Harbor Ship Canal. Although much remedial work has been accomplished in these areas, certain water quality standards are still not being met.

2.2.4.4 Lake Erie

Lake Erie is generally considered eutrophic, and open-lake concentrations of phosphorus have not changed significantly despite efforts to reduce total phosphorus loading. Some areas of the deeper waters of Lake Erie often become devoid of oxygen during the summer months. This restricts the habitat of cold water fish within the lake and promotes nutrient recycling.

Discharges of municipal and industrial wastes into the Detroit River (and ultimately Lake Erie) cause water quality problems associated with coliform bacteria, phenols, phosphorus, and total dissolved solids. Many harbour areas are contaminated by agricultural, industrial and municipal discharges. Although watershed remedial programs are in progress, problems still exist with respect to coliforms, oil and grease, nutrients, iron, copper, lead and zinc in these near-shore areas.

2.2.4.5 Lake Ontario

Lake Ontario is also showing some of the signs of degradation evident in Lake Erie. The algae Cladophora sp. has become a nuisance along the shorelines and problems with dissolved oxygen, total dissolved solids, and coliform bacteria have been identified in Hamilton and Toronto Harbours. Although total phosphorus levels have declined since 1978, nitrogen levels have continued to increase. Hazardous chemicals also appear to be a problem as the U.S. EPA (1980) identified cadmium, copper, PCBs, dieldrin, and DDT and its metabolites as exceeding IJC water quality objectives.

2.2.4.6 St. Lawrence River

The water quality of the St. Lawrence River is typical of the water quality of eastern Lake Ontario. The large volume of water flowing into the St. Lawrence River from Lake Ontario assists in the rapid assimilation and dilution of waste loadings. Although the water of the St. Lawrence River exhibits a high degree of quality, there is impairment in localized areas. Nuisance growths of <u>Cladophora</u> and other attached aquatic plants occur in the shallow waters at many locations in the river. Along the U.S. shoreline, local areas of water quality impairment are encountered downstream from a number of municipalities and industries. Comparison of data collected between 1973 and 1977 indicates no significant changes in mean surface water concentrations of total phosphorus in the river. Chloride concentrations in the St. Lawrence in 1977 were 26 to 28 mg/l and have not changed since 1969.

2.3 Development and Economy

2.3.1 Socio-Economic Patterns

The physical environment of the Great Lakes basin has exerted a strong influence over population distribution and types of economic activity in the basin. From the earliest times fish, furs, forests, and fertile lands attracted settlers who built towns along the shorelines and used the Great Lakes to transport their harvests to other parts of the nation. Nineteenth century loggers chopped their way through virgin timber, floating their logs to boom towns along the shores. Logging and fishing were soon replaced by manufacturing industries which concentrated along the shoreline to use the lake waters for shipping and processing. As the automobile industry flourished, workers travelled away from cities to vacation at beaches and resorts on the lakes. Improved roads and freeways shortened travel time between industrialized cities and the shore, making it possible for more people to enjoy seasonal or permanent residences on the Great Lakes. Lands along the Great Lakes continue to support industry, recreation, residential areas, forests, farms and orchards, energy and mining facilities. Waters associated with these lands support commercial navigation, fisheries, recreational boating and waste assimilation, and provide industrial and public water supplies.

The opening of the Erie Canal in 1825, the Welland Canal in 1829 and the locks at Sault Ste. Marie in the 1850s were important events in the economic development of the Great Lakes basin. The opening of the St. Lawrence Seaway in 1959 provided a route for ocean-going vessels to reach into the heart of North America and enabled the Great Lakes to become an international shipping route.

Socio-economic patterns in the Great Lakes basin are affected by the interrelated aspects of population, resources and the economy. These aspects are discussed briefly in the following paragraphs:

2.3.1.1 Population

The major metropolitan areas of the basin (Figure 2-4) have developed in areas that are sensitive to man-made changes. They include sheltered bays such as Saginaw Bay on Lake Huron and Burlington Bay on Lake Ontario, inter-connecting waters such as Lake St. Clair and the Detroit River, and the mouths of rivers such as the Maumee River which flows into Lake Erie. The establishment of these metropolitan areas has been influenced by the provision of sheltered harbours, the comparative ease of shipping bulk materials by waterborne transport, the availability of raw materials and an abundant water supply for manufacturing.

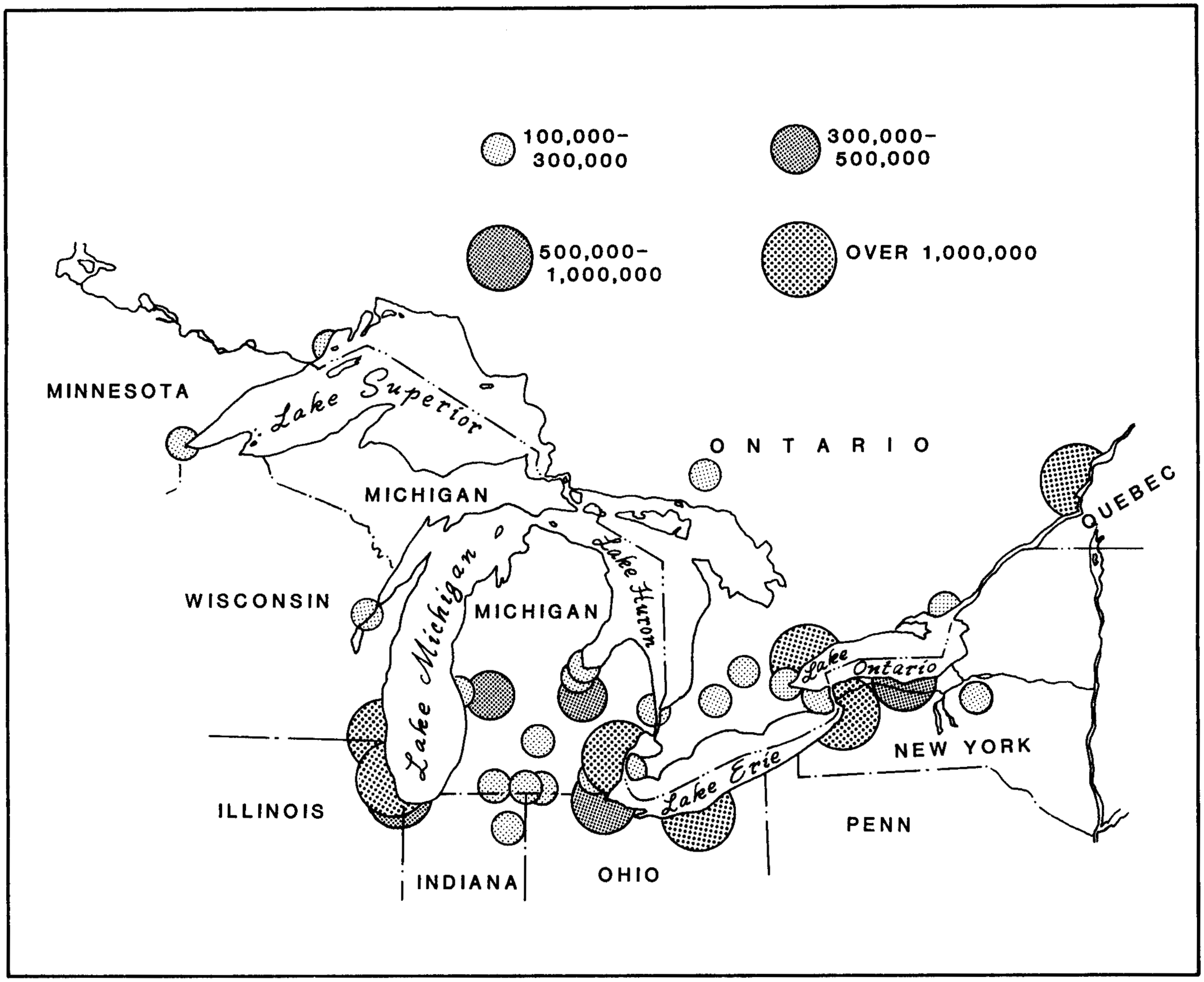
Demographically, the Great Lakes basin supports about 36,000,000 people (one third of Canada's population and one seventh of the population in the United States). The basin generates one third of Canada's national income and one sixth of that of the United States. It is the center of heavy industry in North America.

Population growth in the Lake Superior basin has been slow, increasing from about 400,000 in 1900 to 660,000 in 1975. The Lake Michigan basin population has increased more than threefold from about four million in 1900 to 14.2 million in 1975. The population of the Lake Huron basin, although growing at a rate comparable to other regions, particularly in Canada, has remained relatively small, increasing from 414,000 in 1900 to about 1.9 million in 1975. Most of the U.S. population expansion in the Lake Huron basin has occurred in the Saginaw River drainage area. The Lake Erie basin, the most densely populated basin, has shown great population growth since 1900 when about three million people were enumerated. The 1975 population was more than 13.2 million. The Lake Ontario basin, which was settled earlier than the other four, had a population of about 1.4 million in 1900 and 6.3 million in 1975.

2.3.1.2 Resources

The Great Lakes basin is rich in renewable natural resources and recreational opportunities, as well as non-renewable mineral resources, all of which make an important contribution to the basin's economy.

The Great Lakes basin includes a wide variety of agricultural activities, including dairying, livestock production and grain, tobacco, vegetable and fruit farming. Agricultural lands are found primarily in eastern Wisconsin, northern Indiana, northern Ohio, southern Michigan, and southern Ontario. The farms in the basin produce seven percent of all U.S. farm output and 25 percent of Canada's farm output.



Population Centers in the Great Lakes Basin

Figure 2-4

There are 59,000 square miles of commercial forest in the United States portion of the basin and over 70,000 square miles in the Canadian portion. Production of pulpwood, saw logs, veneer logs, and miscellaneous industrial timber products is substantial.

Commercial and sport fishing in the Great Lakes are both important activities in the basin; however, the relative annual contribution of commercial fishing to the basin's economy has declined in the last several decades, due to the decline of fish stocks preferred for human consumption.

Mineral production in the western Great Lakes region produces about two thirds of the U.S. output of iron ore and one twentieth of its domestic copper output. The Laurentian Shield north of Lake Huron provides rich lodes of nickel, copper, and uranium for Canada's mineral production. Significant amounts of crushed limestone, cement, clay and gravel aggregates are produced in the basin and transported via the Great Lakes waterway. Natural gas reserves also exist in the basin, especially in the Lake Erie region. The importance of these reserves will undoubtedly grow as world energy supplies decline.

2.3.1.3 Economy

The economy of the Great Lakes basin is basically industrial. Industries in the basin utilize the transportation and power advantages offered by the Great Lakes-St. Lawrence River system. Other important elements of the basin economy are agriculture, mining, forestry production, commercial fishing, tourism, commerce and finance.

Because the U.S. portion of the basin has a larger population and a far greater level of development, it is understandable that economic activity on the U.S. side would have a greater monetary value than that in Canada. Nevertheless, the levels of population, industrial development and agricultural production in the basin in Canada make this relatively small part of Canada the most important contributor to Canada's economy. In 1974, the latest year final statistics are available, about 51 percent of the total value of shipments by the Canadian manufacturing sector was accounted for by Ontario-based industry. The basin is the primary focus of the iron and steel industry in North America, accounting for 40 percent of the U.S. production and 80 percent of the Canadian output. There are also high national proportions of other industries in the basin, including chemical, petroleum refining, food products, paper products, machinery, transportation equipment, fabricated metal products and waterborne transportation. Four major commodities - iron ore, coal, crushed limestone and grain - are distributed through the Great Lakes-St. Lawrence Seaway from ports associated with major shoreline cities and, more recently, the transshipment of western coal through the lakehead ports on Lake Superior. These items account for 85 percent of the waterborne traffic, the balance consisting of petroleum products, cement, chemicals and general cargo.

Although the Ontario portion of the Great Lakes basin, in particular, has experienced growth at or above national rates, the U.S. basin's growth rate has been below the national average in the past 25 years. Because the region has a large number of the slower growth industries, the projected rate of growth is lower than the U.S. economy as a whole, and relatively lower than that for Ontario.

Finally, the economy of the basin is influenced by an extensive recreation and tourism industry. The value of tourism in the U.S. portion of the Great Lakes basin has been estimated at $300 million annually. Canadian figures indicate that international tourism expenditures in the Great Lakes basin totalled over $500 million in 1971. The value of Canadian inland waters in all aspects of waterbased recreation was about $1.5 billion in 1972 and is increasing annually at a 16 percent growth rate, with a major part ascribed to the Great Lakes and its tributary areas.

2.3.2 Transportation

Shipping on the Great Lakes began in 1679 when LaSalle's vessel, the Griffin, embarked into Lake Erie and was lost on its maiden voyage a month later in Green Bay, Lake Michigan. By the mid-1700s various British sailing ships had begun operations on Lake Erie, and American ships on Lake Ontario. These vessels were wooden, sail-powered schooners or brigs. Around 1815-1818, steam powered vessels were introduced. With the completion of the Erie Canal in 1825 and Welland Canal in 1829, the Great Lakes shipping boom began. During the 1830s the major vessels were sail or steam-powered; by the 1850s coal-burning, steam-powered vessels were used extensively for commercial shipping. Today, nearly all Great Lakes vessels are powered by fuel oil.

The basin occupies a location strategic to the highly industrialized and well-populated north-central United States and south-central Canada and is astride the transcontinental link between the major agricultural production regions of the west and midwest and the consuming areas of the east. The Great Lakes-St. Lawrence system provides 27-foot deep navigation channels from Duluth-Superior to Montreal and 35-foot least depth channels from Montreal to Quebec City. Over 100 billion ton-miles of waterborne freight are carried by this system each year.

The region around the basin can be considered tributary to Great Lakes harbours for shipment of overseas general cargo. In the United States, the region includes the eight lake-bordering states and eleven additional nearby states which generate about 25 percent of the U.S. general cargo export traffic. The tributary areas produce 79 percent of U.S. grain for overseas shipment with the six midwest states bordering the Great Lakes producing 37 percent. However, U.S. grain exports through Great Lakes harbours were only 10 percent of the total exported in 1980. Almost half of the Canadian wheat export shipments pass through Great Lakes-St. Lawrence ports and approximately one third of all Canadian ship cargos are handled in the system.

The railroads, motor carriers, airlines, barge companies and pipelines serving the region tributary to the Seaway system are extremely active competitors for much of the cargo tonnage which moves or could move through the Great Lakes-St. Lawrence Seaway system. However, such carriers assume a complementary service role for most of the domestic and overseas traffic actually moving through the system. As partners in the total physical distribution process, they transport freight to and from Great Lakes ports and inland origins or destinations.

In 1953, a record 128 million tons of freight moved through the locks at Sault Ste. Marie. This record still stands. During the last 10 years, shipping through these locks averaged 81 million tons. Two thirds of the iron ore produced in the United States and Canada is shipped through this facility.

For the last ten years, the Welland Canal has passed an average of 65 million tons/yr.; 45.2 percent of the cargos were mine products and 39.7 percent agricultural products; of this canal traffic, 52 percent was Canadian and 48 percent, U.S. The ten year average for the St. Lawrence Seaway has been 55 million tons/yr., of which 66 percent was Canadian traffic and 34 percent, U.S. This cargo consisted of 36.9 percent mine products and 45.0 percent agricultural products.

2.3.3 Power

Water required for power generation processes represents the largest demand on water resources within the Great Lakes basin. One of the interests that would be affected by regulation of any or all of the Great Lakes is hydro-electric power since such installations are located on all the international connecting and outlet channels of the Great Lakes except the St. Clair-Detroit Rivers.

Diversion of water from the Niagara River above the falls for power purposes commenced in the late 1880s. In the year 1900 the diversion totaled about 6,000 cubic feet per second (cfs). By 1921, the amount diverted was approximately 50,000 cfs. With the completion in 1926 of the first of the high-head plants, Sir Adam Beck No. 1, a further 14,000 cfs bypassed Niagara Falls. During the Second World War, increased diversion by Canada was permitted and, in 1954, the units of the Sir Adam Beck No. 2 plant came into service. This plant reached full capacity in 1958, bringing the maximum diversion through the Beck developments to 60,000 cfs. The Robert Moses Niagara plant on the United States side of the river, immediately upstream of the Sir Adam Beck plants, came into service in January 1961 and reached full capacity in 1962. It has a design capacity of 83,000 cfs, but on occasion has diverted up to 105,000 cfs.

Ontario Hydro is responsible for generating electricity from the Canadian share of the flow in the Niagara River (including the DeCew power plants diversion from the Welland Canal) and in the St. Lawrence River in the International Rapids Section. Hydro-Quebec utilizes the full flow of the St. Lawrence at its Beauharnois-Cedars development. In addition, Great Lakes Power Company has a power plant located at Sault Ste. Marie, Ontario, the capacity of which is currently being expanded. Approximately 15 percent of the total hydro-electric generating capacity in Canada is located on the outflow rivers of the Great Lakes and amounts to 4,807,000 kilowatts. Almost half of the thermal generating capacity in Canada (4,474,000 kilowatts) is located along the Great Lakes and outlet rivers.

The U.S. portion of the Great Lakes basin had an electric generating capacity of 32.8 million kilowatts in 1970. This represented 9.6 percent of national production. The total installed hydro-electric capacity located on the United States side of the outflow rivers is approximately 3.2 million kilowatts. The principal power producer is the Power Authority of the State of New York, which utilizes the U.S. portion of the flows of the Niagara River and of the St. Lawrence River in the International Rapids Section. There are also two small hydro-plants on the St. Marys River at Sault Ste. Marie, Michigan, one owned by the U.S. Government and the other by the Edison Sault Electric Company, and several small plants associated with the New York State Barge Canal.

Power generated from the existing hydro-electric installations is cheaper than power produced at fossil- or nuclear-fueled installations; maximum utilization of the hydro-electric power capacity, therefore, is economically advantageous.

2.3.4 Cultural Developments

This section describes the land uses of the Great Lakes shoreline. The shore zone, which includes the dry land, water, and bottomland beneath the water in close proximity to the shoreline, i.e., to the five fathom (30 foot) contour, represents a unique natural resource whose recreational, commercial, and ecological values are high. Major categories of use are residential, industrial-commercial, agricultural/undeveloped, forest, recreation/wildlife preserves, and public institutional holdings.

A most significant aspect of shoreline use in the Great Lakes basin is the amount of shore developed for residential, recreational, and commercial and industrial purposes. The percentages of U.S. and Canadian shoreline so classified are 25, 7.2, and 5.2 percent, respectively. Some area shorelines accommodate greater concentrations of these categories than others. For example, in the lower part of Lake Michigan, 86 percent of the shoreline is developed for recreational, residential, commercial and industrial purposes. Similar high percentages of development exist in the area from Toronto to Hamilton along the western shore of Lake Ontario.

During the last 20 years there has been a moderate increase in the number of shoreline miles in residential development and recreational use and a decrease in agricultural and undeveloped shorelands. A long-term projection of this trend would demonstrate that most of the Great Lakes shoreline is expected to be in urban-serving uses by 2020. Corresponding to the increase in residential development and recreational use, public ownership of shorelands has increased, but at a more modest rate. Of the 3,756 miles of Great Lakes shoreline in the U.S., 3,029 miles (81 percent) are privately-owned. Most Canadian shorelands are privately-owned also, but the proportion is only 57 percent. The non-federal public owns 14 percent of the U.S. miles and 38 percent of the Canadian miles.

Due to growing pressures on recreational resources in the Great Lakes region, long-range planning and development has received increased attention. Public lands and water areas within the region have been set aside for outdoor recreation. Developments include federal, provincial, state, county and local parks and forests; marinas and campgrounds; educational arboretums, gardens, and nature centers; wildlife refuges and game areas; recreational areas for ORVs and snowmobiles as well as wilderness reserves. There are also numerous privately developed recreational facilities throughout the region.

The absence of strongly developed relief in many parts of the basin limits the amount of land with characteristics that create high quality settings, especially in the lake plains. As a result, many areas have only limited potential for the development of recreational facilities with high quality aesthetic appeal, thus making the Great Lakes shoreline locations an even more attractive source for recreational satisfaction. Great Lakes water surfaces and shorelines receive intensive weekend and vacation use by both residents and non-residents of the basin.

Tables 2-9 and 2-10 summarize ownership, use and length of shoreline in the United States and Canada for the five Great Lakes.

Section 3

FLUCTUATION OF WATER LEVELS AND FLOWS

3.1 General

The level of a lake depends on the balance between the quantity of water entering the lake and the quantity of water leaving the lake. If these quantities are exactly the same, the general lake level is constant. If more water enters the lake than leaves it, the volume of water in the lake increases and the lake level rises and, with no artificial outlet control, its outflow increases. The amount of lake level and outflow fluctuation in the Great Lakes system depends on the magnitude of water supply changes and the timing of the passage of the water through the system. These, in turn, are the result of the interaction of the natural and artificial factors which affect the supply and discharge of water to and from the system. The range of fluctuation of water levels and outflows is also directly affected by the area and the discharge capacity of the lake's outlet river. The discharge capacity of the outlet river is influenced by erosion, dredging, construction and crustal uplift.

There are three categories of water level fluctuations on the Great Lakes: long-term, seasonal and short-period.

Long-term fluctuations are the result of persistent low or high water supply conditions within the basin which result in extremely low levels, such as were recorded in the mid-1960s on Lakes Michigan-Huron, Erie, and Ontario, or in extremely high levels, such as in 1973-74 on all the lakes except Lake Superior. A century of water level records in the Great Lakes basin are proof of the fact that no regular, predictable cycle exists. The intervals between periods of high and low levels, and the length of such periods can vary widely over a number of years. Maximum recorded ranges of levels (1900 to date), from extreme high to extreme low, have varied from 3.8 feet on Lake Superior to 6.6 feet on Lake Ontario. The range in levels of each of the downstream lakes reflect not only the fluctuations in supplies to its own basin, but also the fluctuations in supplies from the upstream lakes.

Seasonal fluctuations in Great Lakes levels reflect the annual hydrologic cycle. These fluctuations are characterized by higher net supplies during the spring and early summer with lower net supplies during the remainder of the year. The magnitude of seasonal fluctuations is quite small, averaging about one foot on Lake Superior and Lakes Michigan-Huron, 1.2 feet on Lake Erie and 1.9 feet on Lake Ontario.

Short-period fluctuations, lasting from a few hours to several days, are caused by meteorological disturbances. Wind and differences in barometric pressure create temporary imbalances in the water levels at various locations on the lakes.

Superimposed upon all three categories of water level fluctuations are wind induced waves.

3.2 Natural Factors Affecting Fluctuations

The factors which affect short-period, seasonal and long-term fluctuations in Great Lakes levels can be separated into two categories - natural and artificial. The principal natural factors, which are discussed briefly in the following subsections, include precipitation, evaporation, runoff, groundwater, ice retardation, aquatic growth and meteorological phenomena. A pictorial representation of some of the principal factors is shown in Figure 3-1. Artificial factors are discussed in Subsection 3.3. A complete discussion of these factors is contained in Appendix "A" of the 1973 International Great Lakes Levels Board report.

3.2.1 Precipitation

The source of water reaching the Great Lakes is precipitation which falls in the form of both rain and snow on the lakes and on tributary land areas. Protracted excesses or deficiencies in precipitation are largely responsible for the long-term variations in lake levels. The historical variation in precipitation is shown in Figure 3-2. Record high precipitation in the late 1940s and the early 1950s (five of the six years prior to 1952 had above-normal precipitation), with resultant high lake levels, was followed only 12 years later by five years of below-normal precipitation and record low lake levels in the 1960s.

3.2.2 Evaporation

Protracted deficiencies or excesses in evaporation generally accompany excesses or deficiencies, respectively, in precipitation. These conditions thus reinforce each other in producing long-term variations in lake levels. The magnitude of the evaporation from each of the lakes over a 10-year period and its relationship to precipitation on the lakes during that period, are shown in Table 3-1.

3.2.3 Runoff

The land area contributing runoff to the Great Lakes varies in width around most of the lakes from less than 10 miles to about 100 miles. The Great Lakes drainage system consists of many perennial and intermittent streams, many of which are small in terms of area drained. The percent total Great Lakes basin land area boasting of hydrologically monitored tributaries range from 72 percent for Lake Erie to 53 percent for Lake Superior.

3.2.4 Groundwater

The Great Lakes are groundwater discharge zones. Regardless of the actual direction of groundwater movement in the Great Lakes Basin

Natural Factors Affecting the Levels of the Great Lakes

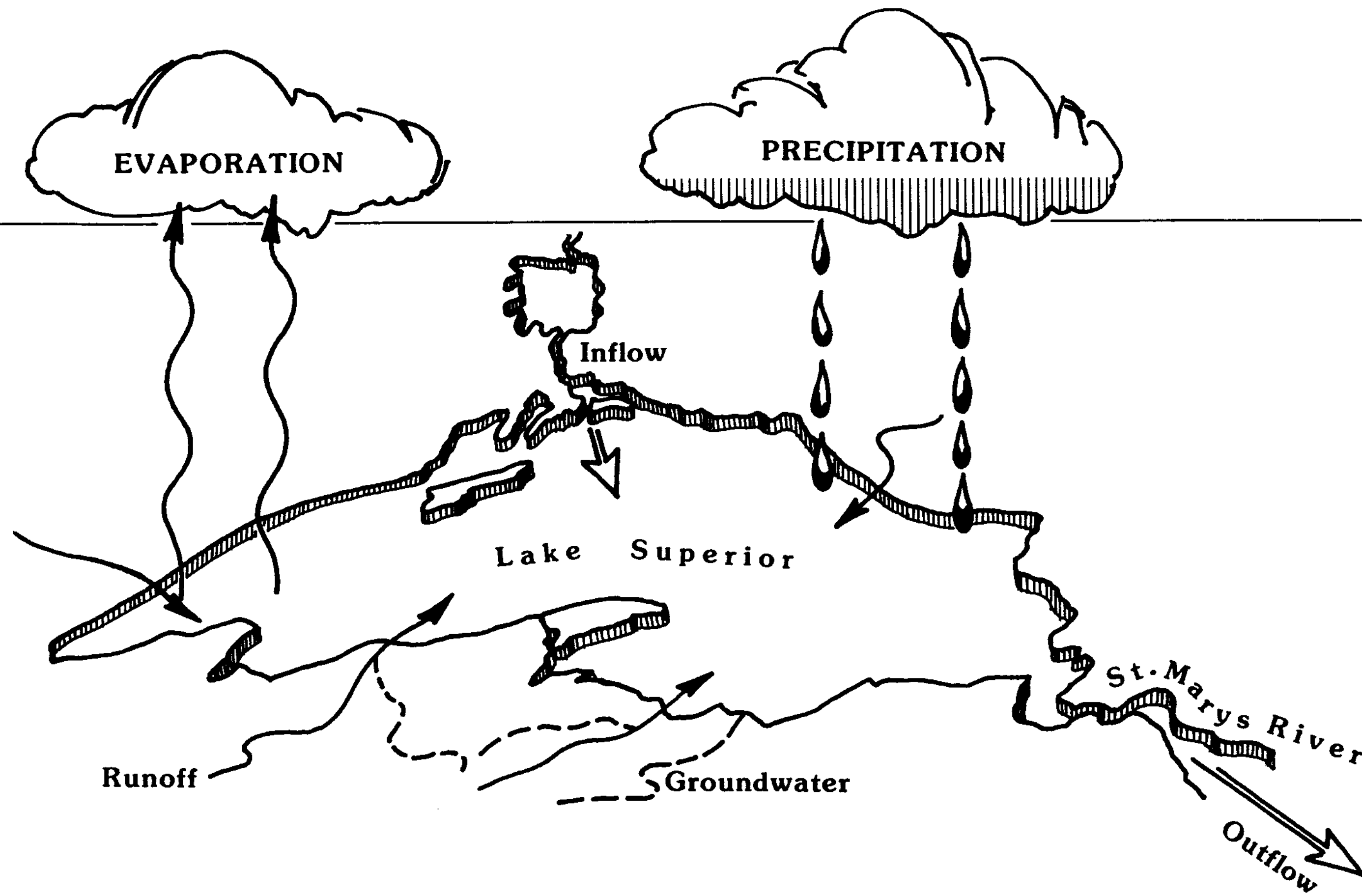


Figure 3-1

Average Annual Precipitation
Entire Great Lakes Basin

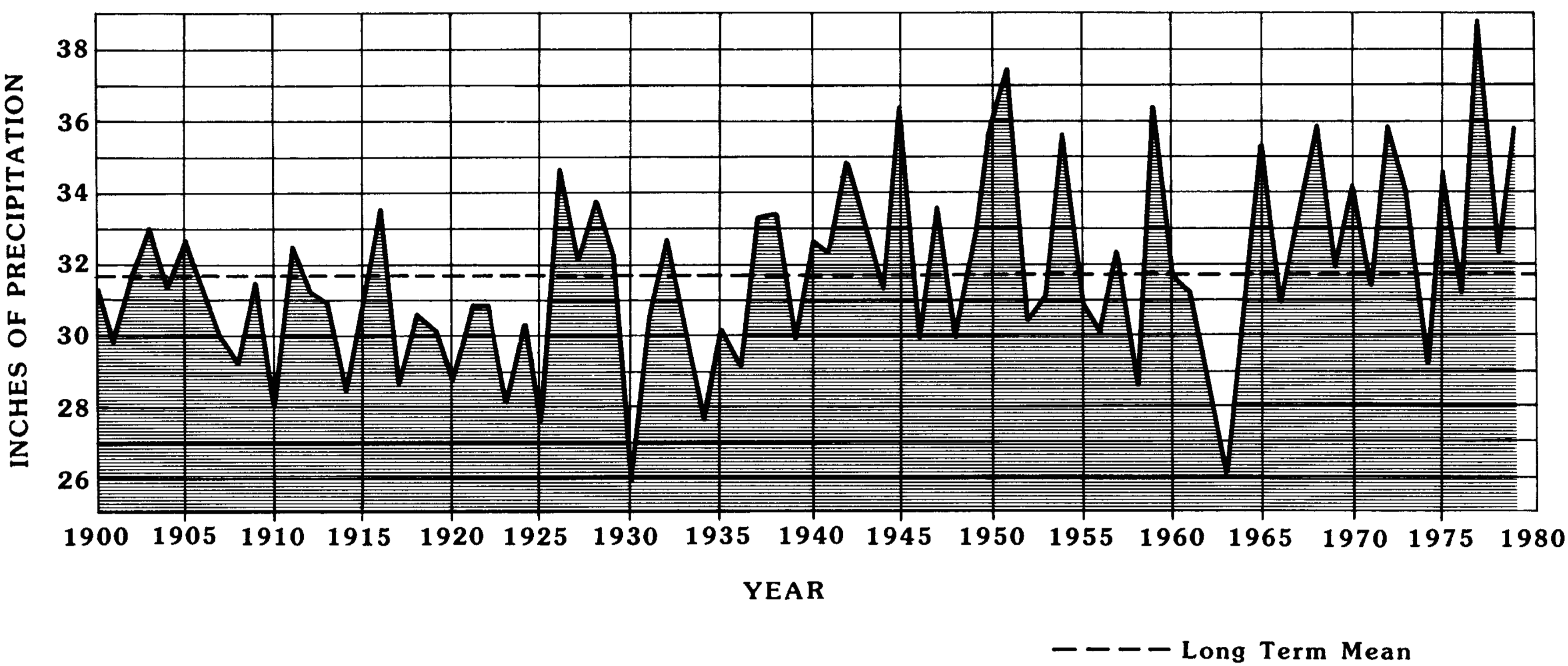


Figure 3-2

Table 3-1

RELATIONSHIP BETWEEN EVAPORATION AND PRECIPITATION
ON THE SURFACE OF THE GREAT LAKES
(Based on Data for the Period Oct. 1950 - Sept. 1960)

Lake(s)	Approx. Average Annual Evaporation from Lake Surface (Inches)	Average Annual Precipitation on Lake Surface (Inches)	Average Annual Evaporation as a Percentage of Average Annual Precipitation on Lake Surface
Superior	22	32	69
Michigan-Huron	26	33	79
Erie	36	36	100
Ontario	25	34	74

Table 3-2

EFFECTS OF ICE RETARDATION ON WINTER FLOWS (JAN. THROUGH MAR., INCL.)
IN THE GREAT LAKES CONNECTING CHANNELS AND ST. LAWRENCE RIVER

Outlet River	Average Annual Flow (cfs) (1900-1978)	Estimated Average Ice Retardation (cfs)	Percent Retardation
St. Marys	75,000	3,000*	4*
St. Clair	180,000	28,000	16
Detroit	184,000	8,000	4
Niagara	203,000	4,000	2
St. Lawrence	238,000	7,000*	3*

*Prior to regulation.

watershed, groundwater discharges either directly to the lakes themselves or as baseflow to streams, thereby becoming inflow to the lakes. Significant outflow from the Great Lakes basin via groundwater flow systems is unlikely. Studies under the 1973 International Field Year for the Great Lakes (IFYGL) did quantify groundwater discharge to Lake Ontario. In terms of the total Great Lakes water balance, groundwater contributions directly from the shorelines of the lakes are likely to be very small, probably no greater than the accuracy in measuring the surface water inflow and outflow to the lakes.

3.2.5 Ice Retardation

Flows in the outlet rivers of the lakes during the winter season are often retarded materially by ice formation and by ice jamming. These conditions are not predictable for any specific winter, either as to their severity or the exact timing of their occurrence. Average reductions in the outflow rates, for the period January through March, are indicated in Table 3-2.

The natural retardation of flows under ice conditions causes the levels of unregulated lakes to be higher during spring breakup than would be the case if there were no ice. This increases the storage on the lake. Such increased storage causes higher outflows following the breakup, and the seasonal effect is gradually dissipated during the open-water period. The subject of flow retardation is further discussed in Section 5.

3.2.6 Aquatic Growth

Aquatic growth in the rivers during the summer also retards outflow by varying amounts from river to river. In the Niagara River, for example, comparison of discharge curves developed during periods of both minimum and maximum aquatic growth indicates that such retardation could reduce outflows by as much as 10,000 cfs during the months of June to September. For further discussion on this matter, see the Lake Erie outflow report prepared by the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data, dated June 1976. This retardation generally starts in May, averages about 1,900 cfs, and increases to its maximum in July. Retardation undergoes a drastic reduction in the fall, as aquatic growth lessens, and it becomes insignificant by November.

3.2.7 Meteorological Disturbances

Meteorological phenomena may create large short-term fluctuations in lake levels which last for periods from minutes to several days. Sustained high winds along the major axis of the lake may cause the surface of the lake to tilt, rising at one end and falling at the other. Cessation of such conditions may result in oscillations, with a rapid change in lake level. Buffalo Harbor, at the east end of Lake Erie, has experienced a rise of as much as eight feet, due to these phenomena. Atmospheric pressure changes also produce sudden temporary lake level fluctuations. One such event occurred on Lake Michigan on June 26, 1954 at 1:26 p.m., causing a sudden and unexpected rise of one and one-half feet above the day's average lake level in Chicago's Montrose Harbor and resulting in several drownings.

3.3 Artificial Factors Affecting Fluctuations

The artificial factors affecting fluctuations in Great Lakes levels include dredging, diversions, consumptive use, and outflow regulation. This section of the report briefly covers dredging and outflow regulation. Diversions are discussed in detail in Section 4 and consumptive uses in Section 6.

3.3.1 Dredging

Dredging to increase a lake's outflow capacity is often an integral part of the works to provide some control of the levels and outflows. Through the operation of a control structure, the levels can be manipulated to some degree in accordance with a predetermined policy.

The levels of Lakes Michigan-Huron have been lowered by commercial dredging for gravel and by dredging operations undertaken to improve the St. Clair and Detroit Rivers and Lake St. Clair for navigation.

The 1926 report of the Joint Board of Engineers, entitled "St. Lawrence Waterway," attributes about 0.3 foot of lowering of Lakes Michigan-Huron levels to commercial dredging of gravel from the reach of the St. Clair River in the vicinity of Point Edward, Ontario, between 1908 and 1925.

Channel enlargements in the St. Clair and Detroit Rivers temporarily increased the inflow to Lake Erie. This caused a rise in Lake Erie levels which, in turn, was reflected by increased outflow from this lake. The transitory effect, caused by the 27-foot deepening during 1958-1962, became negligible in 1969.

The levels of Lake Erie have not been affected by any dredging in the Niagara River.

3.3.2 Current Regulation of the Great Lakes

Lake Superior outflows have been under complete control since 1921. The current regulation plan, known as Plan 1977, was approved for use by the IJC in October 1979.

Lake Ontario outflows have been regulated since 1958. The plan currently in use is Plan 1958-D.

Regulation of Lake Superior has changed the sequence and magnitude of the releases from that lake. This change has affected the levels and outflows of the downstream lakes. Table 3-3 shows that if regulation of Lake Superior had been conducted under the current plan of operation (Plan 1977) over the entire period, 1900-76, the long-term mean level would have been raised and the range of levels reduced when compared to unregulated conditions. The table also shows that the long-term mean levels of the other lakes would not have been materially affected, although the extreme stages would have been reduced.

Table 3-3 also shows that if Lake Ontario had been regulated over the period 1900-1976 under the current plan of operation, the range of levels would have been increased when compared to unregulated conditions. However, it is to be noted that the regulation of Lake Ontario, including the International St. Lawrence River Board of Control's discretionary authority under operation since 1960, has brought about a range of levels on Lake Ontario approximately 1.3 feet less than what it would have been without regulation.

3.4 Supply and Diversion Summary

The average annual values of the several previously discussed factors affecting supply, together with the lake outflows and existing diversions, and, where applicable, the inflow from the upstream lakes, are shown diagrammatically on Figure 3-3. The diagram was drawn as though there were no change in the storage within the lakes from the beginning to the end of the illustrative period used, October 1950 to September 1960. Thus, it is representative of the relative values of the inputs and outputs to each of the lakes in a state of storage equilibrium, with the sum of the inputs to each lake being exactly equal to the sum of the outputs.

3.5 Regulation Characteristics

The vast water surface areas of the Great Lakes constitute a feature unique to the Great Lakes-St. Lawrence River system. Small changes in the levels of the lakes account for large quantities of water.

The immense storage capacity of the lakes in combination with their restricted outflow make them a highly effective naturally-regulated water system. The effectiveness of the natural regulation is shown by the relatively small variations in levels from summer to winter, and from extreme low to extreme high, as shown in Table 3-4.

Natural regulation of a lake exists when its outflows are uniquely related to its level or to its level and that of a downstream lake, and ca be expressed in terms of a stage-discharge or slope-stage-discharge relationship. In the Great Lakes the outflows from Lakes Superior and Ontario are artificially controlled, and may be varied within limits at an given water level. The outflow from Lakes Michigan-Huron is through the St. Clair and Detroit Rivers into Lake Erie, and depends basically on the levels of the upstream and downstream lakes. The major portion of the outflow from Lake Erie occurs through the Niagara River with a relatively small portion being diverted to Lake Ontario through the Welland Canal and the New York State Barge Canal. Therefore, the major portion of the outflow depends on Lake Erie levels. Stage-discharge relationships for uncontrolled outflow channels may be expressed in terms of lake level alone, or lake level and slope in the river. By the nature of the Great

Table 3-3

CALCULATED EFFECTS OF LAKE REGULATION
SUMMARY OF RANGES OF STAGE IN FEET
AND OUTFLOW IN THOUSANDS OF CUBIC FEET PER SECOND
1900-1976

A. LAKE SUPERIOR - REGULATED AND UNREGULATED

	Lake Superior regulated (1)		Lake Superior unregulated (2)	
	Stage	Outflow	Stage	Outflow
Lake Superior				
Mean	600.44	78	600.10	78
Max.	601.93	123	602.02	117
Min.	598.69	55	598.02	40
Range	3.24	68	4.00	77
Lakes Michigan-Huron (3)				
Mean	578.27	185	578.28	185
Max.	581.16	232	581.21	233
Min.	575.46	112	575.14	113
Range	5.70	120	6.07	120
Lake Erie				
Mean	570.76	207	570.76	207
Max.	573.60	270	573.65	272
Min.	568.10	152	567.85	147
Range	5.50	118	5.80	125

B. LAKE ONTARIO - UNREGULATED (4)

	Lake Superior regulated (1)		Lake Superior unregulated (2)	
Lake Ontario				
Mean	244.86	242	244.87	242
Max.	248.75	331	248.90	334
Min.	241.52	169	241.41	167
Range	7.23	162	7.49	167

C. LAKE ONTARIO - REGULATED (5)

	Lake Superior regulated (1)		Lake Superior unregulated (2)	
Lake Ontario				
Mean	244.73	242	244.74	242
Max.	249.47	310	250.50	310
Min.	241.59	188	241.36	188
Range	7.88	122	9.14	122

NOTES:

(1) For assumed system conditions, see Subsection 5.6.
(2) 1887 Lake Superior outlet conditions and using average computed ice retardation.
(3) 1962 outlet conditions.
(4) 1955 Lake Ontario outlet conditions.
(5) This does not include the effects of the International St. Lawrence River Board of Control's discretionary actions.

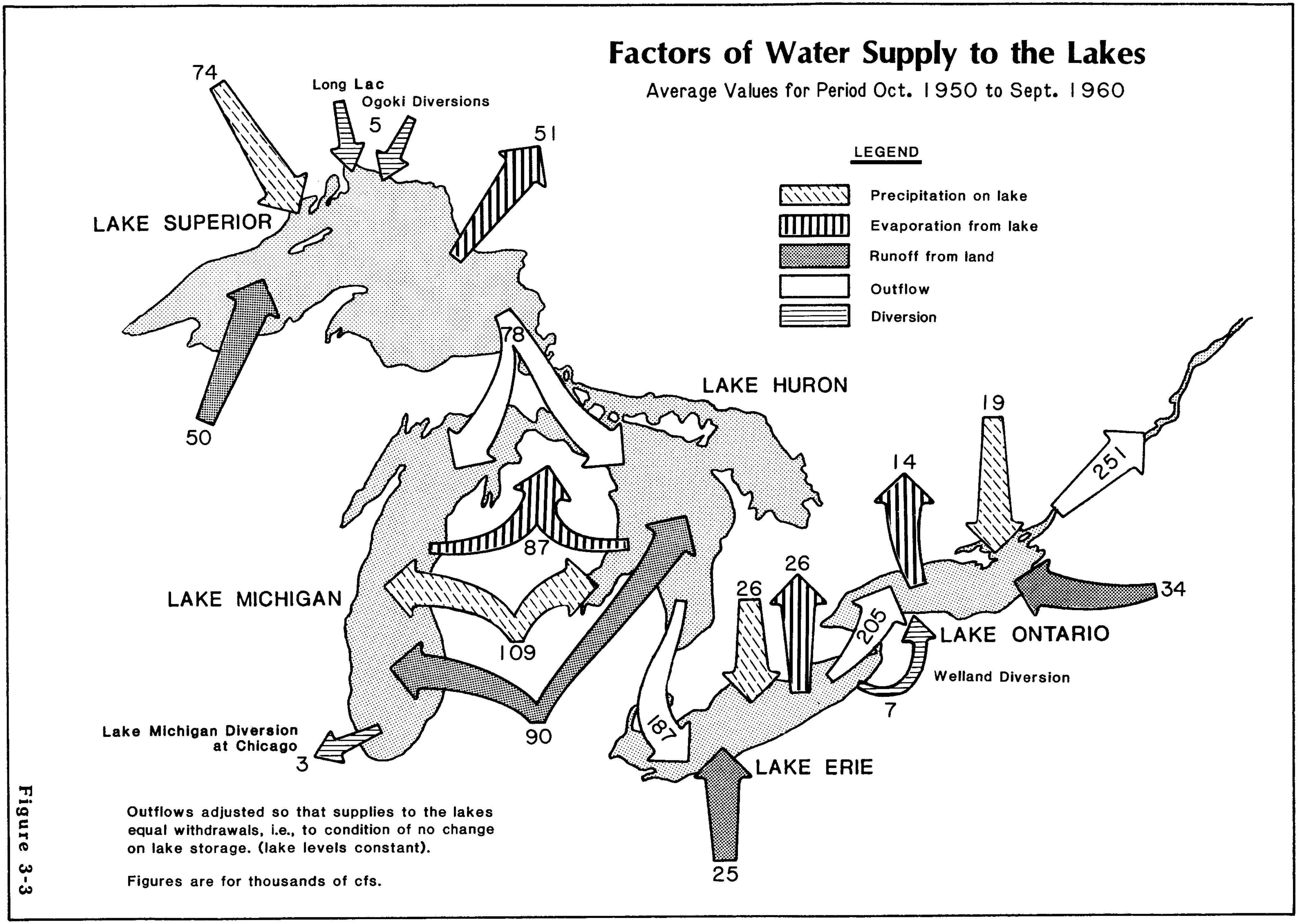

Factors of Water Supply to the Lakes
Average Values for Period Oct. 1950 to Sept. 1960
LEGEND
Precipitation on lake
Evaporation from lake
Runoff from land
Outflow
Diversion
74
Long Lac
Ogoki Diversions
5
51
LAKE SUPERIOR
50
78
LAKE HURON
19
251
14
87
LAKE MICHIGAN
26
26
34
205
LAKE ONTARIO
109
Welland Diversion
7
187
90
Lake Michigan Diversion
at Chicago
3
LAKE ERIE
25
Outflows adjusted so that supplies to the lakes equal withdrawals, i.e., to condition of no change on lake storage. (lake levels constant).
Figures are for thousands of cfs.

Figure 3-3

Table 3-4
GREAT LAKES PHYSICAL AND HYDROLOGIC DATA
(1900-1978)
All Elevations in feet IGLD (1955)

	LAKE SUPERIOR	LAKE MICHIGAN	LAKE HURON	LAKE ST. CLAIR	LAKE ERIE	LAKE ONTARIO
Elevation of Low Water Datum	600.0	576.8	576.8	571.7	568.6	242.8
Monthly Elevation (a)						
- Average	600.57	578.20	578.20	573.24	570.33	244.69
- Maximum	602.02	581.04	581.04	576.23	573.51	248.06
- Minimum	598.23	575.35	575.35	569.86	567.49	241.45
- Range of Stage	3.8	5.7	5.7	6.4	6.0	6.6
Range, Winter Low to Summer High (Monthly) (a)						
- Average	1.2	1.2	1.2	1.7	1.6	2.0
- Maximum	2.1	2.1	2.1	3.3	2.8	3.6
- Minimum	0.4	0.4	0.4	0.6	0.9	0.7
Recorded Monthly Outflows (b) (cfs) Outlet	St. Marys River	Str. of Mackinac	St. Clair River	Detroit River	Niagara River	St. Lawrence River
- Average	75,000	51,000(c)	180,000	184,000	203,000	238,000
- Maximum	127,000	-	232,000	233,000	274,000	350,000
- Minimum	41,000	-	106,000	112,000	118,000	154,000
Average Annual Outflow in Inches on Total Drainage Basin (d)	12.6	10.9	10.9	10.9	10.5	10.9
Drainage Areas (Sq. Mi.)						
- Land Area (e)	49,300	45,600	51,700	6,100	23,600	26,200(g)
- Water Surface Area (f)	31,700	22,300	23,000	400	9,900	7,600(g)
Storage Capacity Per Ft. Depth (CFS-months)	338,000	481,000		5,000	105,000	80,000

(a) Master gages (L. Superior-Marquette, L. Michigan and Huron-Harbor Beach, L. St. Clair-St. Clair Shores, L. Erie-Cleveland, L. Ontario-Oswego).
(b) Outflows include the effects of diversions.
(c) Approximate.
(d) Drainage basin includes land and water surface areas.
(e) Land areas include the total drainage area to the outlet of the upstream lake.
(f) Water areas do not include areas of connecting channels.
(g) Includes area down to the St. Lawrence Power Project at Cornwall.

Lakes system, the relatively steady outflow from a lake, in comparison with the fluctuating nature of the local supply to that lake, constitutes a continuous source of supply to the lake downstream.

The lake level at any time is a measure of the amount of water in storage at that time; a change in the level from beginning to end of any time interval is a measure of the quantity of water added or removed during that interval. When the net supply (see subparagraph 5.5.1) to any one of the lakes exceeds the outflow, its level rises. When the net supply is less than the outflow, its level falls. For example, a large monthly net supply of water to Lakes Michigan-Huron may be more than twice the discharge capacity of the St. Clair River. During such a month, at least half of the net supply would be added to the water stored in the lake. The resulting rise in the lake level during the month could be about four inches, with a corresponding continuous increase in the rate of discharge through the St. Clair River, from beginning to end of month, of about three percent. This is known as the reservior effect.

The magnitude of the reservoir effect of a lake, a significant factor in lake regulation, is much greater in Lakes Superior and Michigan-Huron than in Lakes Erie and Ontario. (See Table 3-4). This effect involves lake outlet capacity as well as lake storage capacity. Changes in Lakes Superior and Michigan-Huron outflows would affect their water levels much more slowly, due to their large areas, than would changes in Lakes Erie and Ontario outflows affect their water levels.

Because of the size of the Great Lakes and the limited discharge capacities of their outflow rivers, extreme high or low levels and flows persist for some considerable time after the factors which caused them have changed or ceased. Some measure of the importance of this may be judged from the fact that it takes two and one-half years for only half of the full effect of a continuous supply change to Lakes Michigan-Huron to be realized in the outflows from Lake Erie.

As described above, the Great Lakes system is already relatively well regulated, both naturally and under existing regulation plans employed on Lakes Superior and Ontario.

Section 4

EXISTING DIVERSIONS

4.1 General

There are five significant diversions of water into, out of or within the Great Lakes system. These are the Long Lac and Ogoki Diversions from the Hudson Bay drainage basin into Lake Superior, the diversion from Lake Michigan at Chicago into the Mississippi River drainage basin, the Welland Diversion from Lake Erie into Lake Ontario, and the diversion from the Niagara River into the New York State Barge Canal (all of which is returned to Lake Ontario). The locations of these diversions are shown on Figure 2-1.

When a diversion is initiated on a chain of lakes the full effects are not immediate. Lake levels and outflows progressively adjust to the diversion until its full consequential effect is ultimately reached. The full effects of all existing diversions in the Great Lakes basin have been reached.

4.2 Long Lac and Ogoki Diversions

4.2.1 General

The Long Lac and Ogoki Diversions are entirely separate projects even though both are diversions from watersheds of the northward flowing Albany River (the Kenogami and Ogoki Rivers), and both flow into the Lake Superior drainage basin.

Both diversions date back to the early 1940s. While the Long Lac Diversion was first visualized as a southward route for log driving, its importance, and that of the Ogoki, largely arise from the electric energy generation which these flows make possible. In the case of the Long Lac Diversion, the diverted water has carried logs and augmented natural flows in the Aguasabon River since January 1941, and has justified a 40.5 MW hydro-power plant on the Aguasabon River. The Ogoki Diversion to Lake Nipigon has augmented the natural flows driving the hydro-power plants on the Nipigon River since July 1943.

During the period July 1943 to December 1979, an average of about 1,440 cfs had been diverted via the Long Lac route and about 4,150 cfs via Ogoki.

4.2.2 History of the Long Lac and Ogoki Diversions

The possibility of diverting the headwaters of the Kenogami and Ogoki Rivers southward into Lake Superior was recognized in the early 1920s. Feasibility studies of the Kenogami and Ogoki systems were conducted by Ontario Hydro at that time, but no action was taken for almost ten years.

In 1935, the Ontario Department of Lands and Forests (representing the Ontario Government) entered into discussions with four U.S. pulp and paper companies over the possible development of the Long Lake timber limits and the feasibility of diverting Kenogami River water southward as a means of transport for the pulpwood logs. In 1937, the Ontario Government signed an agreement with the Pulpwood Supply Company (formed as a consortium of the four companies) to develop the area. The original purpose of the diversion scheme was to facilitate the driving of pulp logs southward on Long Lake and across the height-of-land to the Aguasabon River where they would be moved by jackladder to Lake Superior for rafting.

Ontario Hydro was also interested in the diversion, as the diverted water would increase the power potential on the Aguasabon River and would provide additional benefits at the Great Lakes power sites downstream. In view of this, an agreement was also reached in 1937 between the Ontario Government and Ontario Hydro whereby the latter would construct the necessary dams and channels on a cost-sharing basis. Construction of the Aguasabon generating station began in 1946 and the plant officially commenced operation on October 15, 1948.

In 1940, by an exchange of diplomatic notes, an agreement was reached between Canada and the United States to the effect that, if Canada and Ontario agreed to proceed immediately with the Long Lac/Ogoki Diversions, the United States would not object to Canada diverting immediately an additional 5,000 cfs at Niagara for power production. Construction was started in December 1940 and the Ogoki Diversion was officially opened in July 1943. There was a further exchange of notes dated November 14, 1941, authorizing the use of this water at either Niagara or through the Welland Canal. The 1950 Niagara Diversion Treaty between Canada and the United States perpetuated the additional 5,000 cfs for Canada from the diversion by indicating in Article III that this water would continue to be governed by the earlier exchange of notes and would not be included in the waters allocated under the provisions of the treaty.

4.2.3 Description of the Present Long Lac Diversion

The Long Lac Diversion connects the headwaters of the Kenogami River, which originally drained north through the Kenogami and Albany Rivers into James Bay, with the Aguasabon River, which naturally discharges into Lake Superior near Terrace Bay, Ontario about 155 miles east of Thunder Bay, Ontario (Figure 4-1). It diverts the runoff from about 1,690 square miles of the Hudson Bay drainage basin into the Great Lakes.

Structurally, the Long Lac Diversion consists of the Kenogami River Control Dam, located 12 miles downstream of Longlac on the Kenogami River, and the South Regulating Dam, five miles south of the lake. Long Lac reservoir is about 52 miles long and has a surface area of about 53 square miles. The normal operating range of the reservoir is 1,021.0 to 1,028.4 feet (GSC)*. The operational procedure is to store the spring runoff in Long Lake for release primarily during the fall and winter months. As the lake approaches the maximum storage level in the spring, water is spilled northward through the Kenogami Control Dam. The

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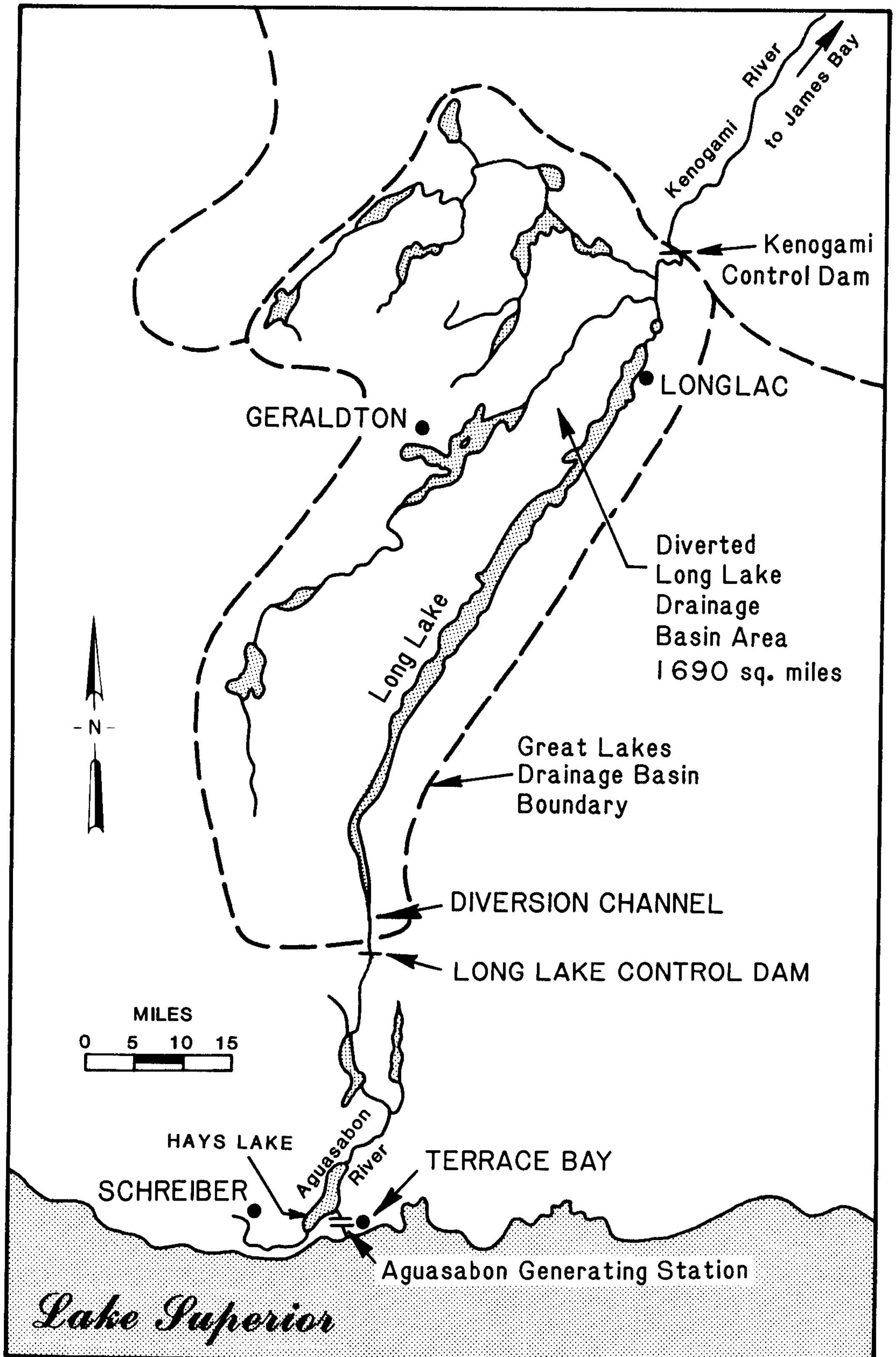
*Geological Survey of Canada datum



Long Lac Diversion Figure 4-1

normal storage capacity of Long Lac reservoir is 4,190 cfs-months. At the south end of Long Lake a diversion channel was cut across the divide and through a series of small creeks and lakes to connect Long Lake to the Aguasabon River. The control works situated at the south end of the channel consist of three concrete structures: an auxiliary dam, a main dam with an emergency sluice and log chute, and a control dam with two 14-foot wide sluices. About 1.5 miles of the Aguasabon River, below the South Regulating Dam, was widened, deepened and straightened to permit the driving of pulpwood. The generating station, located 2.5 miles west of the Hays Lake Dam, has a 3,500-foot intake tunnel conducting water to two turbines. Normal head at the station is about 298 feet. The installed generating capacity is 40.5 Mw. The Aguasabon generating station is connected by a 70-mile 110,000-volt transmission line to the Nipigon River power plants and the provincial grid. In 1947 the Kimberly-Clark Corporation, then sole operators of the Long Lac timber rights, began construction of a 272-ton per day bleached sulphate mill and a 1,500-person townsite at what is now known as Terrace Bay. The pulpmill began operation in 1948.

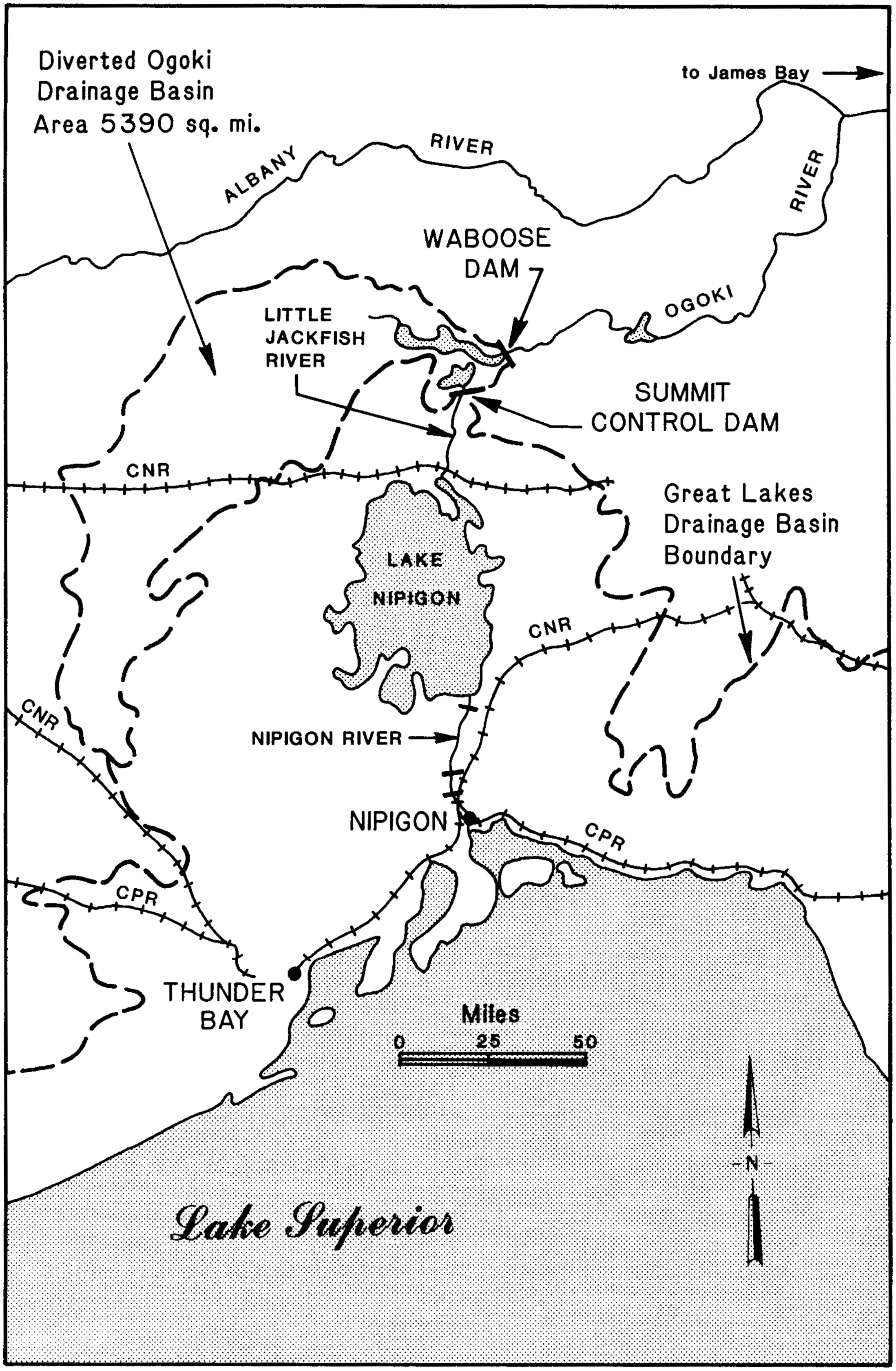
4.2.4 Description of the Present Ogoki Diversion

The Ogoki Diversion connects the upper portion of the Ogoki River (which originally drained through the Albany River into James Bay) with the headwaters of the Little Jackfish River, which flows into Lake Nipigon and thence, through the Nipigon River, into Lake Superior at a point about 60 miles east of Thunder Bay, Ontario (Figure 4-2). The Waboose Dam on the Ogoki River impounds the water that would normally flow northward and redirects it southward into Lake Nipigon. Summit Dam was built to control the rate of diversion into Lake Nipigon, Ontario's largest inland lake.

Located at Waboose Rapids on the Ogoki River, Waboose Dam impounds water from 5,390 square miles of the upper Ogoki River drainage basin for diversion southward. This structure, in conjunction with several earthfill side dams required to prevent flow into low areas, effectively raised the level of the river by 40 feet and flooded Mojikit Lake with an additional 10 feet of water to form the Ogoki reservoir. When at its normal maximum level of 1,073.0 feet (GSC), the Ogoki reservoir occupies an area of about 103 square miles and has a normal storage capacity of about 5,910 cfs-months, but it has relatively little retention capacity. The normal operating range is 6.0 feet. During periods of high water on Lake Nipigon, water is spilled northward through the Waboose Dam.

A channel was excavated through the height-of-land southeast of Mojikit Lake to pass water diverted from the Ogoki River southward through a string of small lakes into the Little Jackfish River. It is here that the Summit Dam controls the diversion flow through the Little Jackfish River into the second reservoir on the system, Lake Nipigon.

Lake Nipigon is 65 miles long, 40 miles wide and has a water surface area of about 1,750 square miles. The lake has a mean depth of 180 feet and a normal storage capacity of 73,790 cfs-months. Ontario Hydro, under a licence of occupation issued and administered by the Ontario Ministry of Natural Resources, regulates the levels of Lake Nipigon to a maximum elevation of 855 feet (GSC) and within a normal operational range of



Ogoki Diversion

Figure 4-2

850-854 feet (GSC). The lake has one drainage outlet, the Nipigon River. Control of Lake Nipigon levels predates the diversion by 18 years when the Virgin Falls Dam was constructed at the Lake Nipigon outlet to control the water supply to the Cameron Falls generating station downstream of the lake and to assist log driving. Flows out of Lake Nipigon are regulated primarily for power generation and are only indirectly influenced by the quantity of the diversion inflow.

Between Lake Nipigon and Lake Superior, the fall in the Nipigon River is about 250 feet, of which 237 feet are utilized at three hydro-power plants - Pine Portage, Cameron Falls and Alexander. The Nipigon River was first used for the production of hydro-electric power in 1920 when the Cameron Falls generating station began operation. The present installed capacity at that station is 72.0 MW. In 1930, 65.2 MW was installed at the Alexander generating station 1.5 miles downstream of the Cameron Falls station. Pine Portage generating station, the latest addition to the system, was built near the outlet of Lake Nipigon in 1950. It has an installed capacity of 128.7 MW, bringing the total installed capacity for the river to 265.9 MW. With the construction of Pine Portage, the use of the Virgin Falls Dam to control Lake Nipigon levels became redundant. Since then the levels have been regulated by the flows through the Pine Portage station.

4.2.5 Environmental Conditions

The Long Lac and Ogoki Diversion project areas are in northwestern Ontario in the physiographic region known as the Canadian Shield, a vast region of eroded igneous, sedimentary and metamorphic rocks. The landscape is mainly one of rolling relief, with a forest-covered terrain of rock knobs and hills containing a myriad of lakes and bogs in the depressions and valleys.

In recent geological time, glaciations have modified the landscape, scraping some rock surfaces bare and leaving extensive deposits of till moraine, and outwash and glacio-lacustrine sands, gravels and clays elsewhere.

Northwestern Ontario is sparsely inhabited. Most economic activity is related to resource extraction industries such as pulp and paper, forestry, mining and hydro-electric production. Tourism and outfitting operations are important to the region's economy. Income is also generated from the trapping of fur-bearing animals and commercial fishing.

Until recently, there had been little detailed investigation of the effects of the diversion projects. Recently, several comprehensive studies have been carried out and reported by Bridger (1978)[20], Peet (1978)[21] and Peet and Day (1980)[22]. A review of these studies indicates that the major impacts have resulted from the construction of diversion structures on the main stem rivers, the construction and alteration of diversion channels, the creation of reservoirs, the greatly altered flow regimes and the use of waterways for log transportation. Some details on the environmental conditions and impacts of the Long Lac and Ogoki Diversions are contained in the following paragraphs.

Long Lac Diversion

Downstream of the Kenogami River Control Dam and the Hays Lake Dam on the Aguasabon River, reduced flows occur in bedrock and coarse gravel controlled channels. The flow reduction in these sections has caused changes, including disruptions to fish spawning areas. Increased and reversed flows have changed the ten-mile section of the Kenogami River south of the Kenogami Dam from a riverine to a lacustrine environment. Due to the altered flow regime and levels, there have been changes in species composition and diversity of flora and fauna. The flooding has created a 140-acre marsh which has been designated as ecologically sensitive due to the large area and diversity of flora and fauna. In Long Lake itself, artificially maintained high water levels contribute to shore erosion in fine-grain deposits and have necessitated some shoreline protection.

The diversion channel, which consists of three canal cuts and four small lakes, was largely constructed in coarse gravels which are not easily eroded. The remaining diversion route to the Hays Lake reservoir, which consists of 17 miles of Aguasabon River channel, is in similar material. However, some additional erosion in river meanders has occurred as a result of the flow increases, and this is contributing to sedimentation in the Hays Lake reservoir. The transport of logs down the diversion channel also contributes to erosion. Downstream exchanges of fish and other fauna are possible now between the James Bay watershed and the Aguasabon River; however, upstream migration is prevented by high flow velocities and the regulating dam.

The Hays Lake reservoir area, like the diversion channel, is largely man-made, and was created by raising the former Blue Jay Lake approximately 55 feet and inundating Big Duck Creek and a portion of the Aguasabon River. Most potential environmental problems were foreseen and avoided in the construction of the reservoir. Although the shores, which consist of coarse gravels, moraine and exposed bedrock, do not represent a serious erosion problem, portions have been stabilized. The reservoir has a 15-foot operating range and has little recreational use. Impacts associated with the reservoir include changes in fish species and the reservoir's action as a settling basin, reducing outflows of suspended matter and turbidity.

Ogoki Diversion

The Waboose Dam has created a mixed river and lake impoundment, inundating the river section by up to 40 feet and Mojikit Lake by about 10 feet. Thus the inundation impacts are less pronounced on the lake.

Immediately below Waboose Dam, fast water habitat that was once important for fish shelter and fish food production has been exposed for periods of up to several years. Releases from Waboose Dam, which are usually of one to four months' duration in late spring and early summer of high runoff years, impact on slow moving organisms in stagnant pools, sweep away silt accumulation and aquatic plants and inhibit riparian vegetation locally.

The upper 22 miles of the diversion route down the Little Jackfish River from Mojikit Lake consists of a series of short steep rapids connecting a system of narrow lakes. Because the path of the diversion is over erosion resistant materials such as boulders, moraine or bedrock, the diversion-induced effects are relatively slight. On the other hand, the lower nine-mile section of the route occupies a narrow, eroded meandering valley of unconsolidated sediments. The river has downcut through these thick unconsolidated sand deposits and, two miles above the mouth, has downcut to lake level. The lower Little Jackfish River biotic system has been subjected to extreme and diverse physical disturbances including high suspended silt concentration, channel bed and bank scouring and wide flow fluctuations. It has been estimated that up to 30 million cubic yards of glacio-lacustrine sediment have been removed in the lower river section since the inception of the diversion, much of it during the first few years of operation. This has resulted in the deposition of material, forming deltaic islands at the mouth of the river in Ombabika Bay at the north end of Lake Nipigon, and increases turbidity in the bay.

4.2.6 Amount of Diversion and Limitations

The Long Lac Diversion began in January 1941, and the Ogoki Diversion started about two-and-a-half years later in July 1943. From July 1943 to December 1979, the combined diversion has averaged 5,590 cfs. The maximum and minimum annual combined diversions have been 8,020 cfs and 2,530 cfs,respectively. Since January 1941, the supply to Long Lake has been approximately 1,700 cfs. Of this amount, 1,420 cfs has been diverted southward into Lake Superior and the remainder, 280 cfs, has been spilled northward down the Kenogami and Albany Rivers into James Bay. On a monthly mean basis, this diversion to Lake Superior has varied between a minimum of 65 cfs and a maximum of 3,500 cfs. Physically, the Long Lac diversion system is limited by several factors: the size of the watershed, about 1,690 square miles; the relatively small storage capacity of Long Lake, about 4,190 cfs-months; the normal range of regulation from 1,021.0 to 1,028.4 feet (GSC), or 7.4 feet; and, the minimum required flow of 800 cfs through the sluiceway for log driving.

Normally all of the Ogoki water is diverted southward to Lake Nipigon. However, there are times during excess inflow to Lake Nipigon when the diversion is partially or completely closed. The diversion is reduced to 4,000 cfs when the Lake Nipigon elevation reaches 854.0 feet (GSC) and is shut off completely when it reaches 854.5 feet (GSC). This precaution against flooding is necessary because the outflow from Lake Nipigon cannot exceed 20,000 cfs due to velocity restrictions at the Canadian Pacific Railway bridge. Since 1943, the diversion has been closed or reduced in flow approximately 20 times. The Ogoki reservoir is then permitted to rise to the maximum level of 1,073.67 feet (GSC) and the excess inflow is spilled down the Ogoki River into the Hudson Bay watershed. The average inflow to the Ogoki reservoir since July 1943 has been about 5,000 cfs; 4,150 cfs has been diverted southward to Lake Superior and the remaining 850 cfs spilled northward down the Ogoki River. Monthly diversions from the Ogoki reservoir have varied from 2,000 cfs to 15,000 cfs. However, the quantities diverted from the Ogoki River in any month are not necessarily representative of the amounts of diverted water reaching Lake Superior in that month since water is stored in Lake Nipigon for later release through the power plants during fall and winter months when inflow is low. Since the Summit Control Dam is left wide open as long as the elevation of Lake Nipigon is below 854.0 feet (GSC), the annual diversion is limited only by the storage capacity of the Ogoki reservoir and the discharge capacity of Summit Dam.

During the periods of high water levels on the Great Lakes in 1951, 1952, 1953 and again in the early 1970s, the Ogoki Diversion was closed off entirely or operated at reduced capacity. There is no international control exercised under the Boundary Waters Treaty over these diversions. However, the amounts of water diverted are reported to the International Joint Commission by the International Lake Superior Board of Control.

4.2.7 Hydrologic Effects of Existing Diversions

The diversions through the Long Lac and Ogoki Diversion Projects have increased Lake Superior's natural supply and decreased that of the Albany River basin. Since the meteorological conditions in the diverted watershed are similar to those which exist in the Lake Superior basin, in periods of drought there is little opportunity to bring extra water from this source into the system when low supply conditions would make it advantageous to do so. The ultimate effect of these diversions on the Great Lakes system, as a whole, has been to increase the levels of the lakes as a result of increasing their supplies. However, since the regulation plans on Lakes Superior and Ontario have been designed to take into account these increased water supplies, the maximum criteria levels are unaffected by these diversions.

4.3 Lake Michigan Diversion at Chicago

4.3.1 General

The Lake Michigan Diversion at Chicago, under way since the early 1800s, has involved the diversion of water from Lake Michigan or its adjacent land areas for various purposes - water supply, sewage disposal, power generation and navigation.

4.3.2 History

The Illinois, DesPlaines and Chicago Rivers were used for canoe traffic as early as 1816, and, by 1840, steamboats were common on the Illinois River below Peoria. Recognizing the potential for interstate commerce on the Illinois River, the U.S. Congress, in 1822, passed an improvement act which authorized the diversion of Lake Michigan water at Chicago and made possible the construction of the Illinois and Michigan Canal. Completion of the canal in 1848 enabled muledrawn barges to travel between Lakes Michigan and LaSalle, and revolutionized passenger and freight traffic, an initial step in making Chicago a major transportation centre. Prior to 1900, low dams were built at five locations along the river, including Marseilles and LaGrange. The primary purpose of four of these dams was to improve navigation and the fifth, at Marseilles, was built for power generation. These dams were later replaced by higher navigation dams. Up to 1900, water diverted from Lake Michigan to this canal system averaged about 500 cfs.

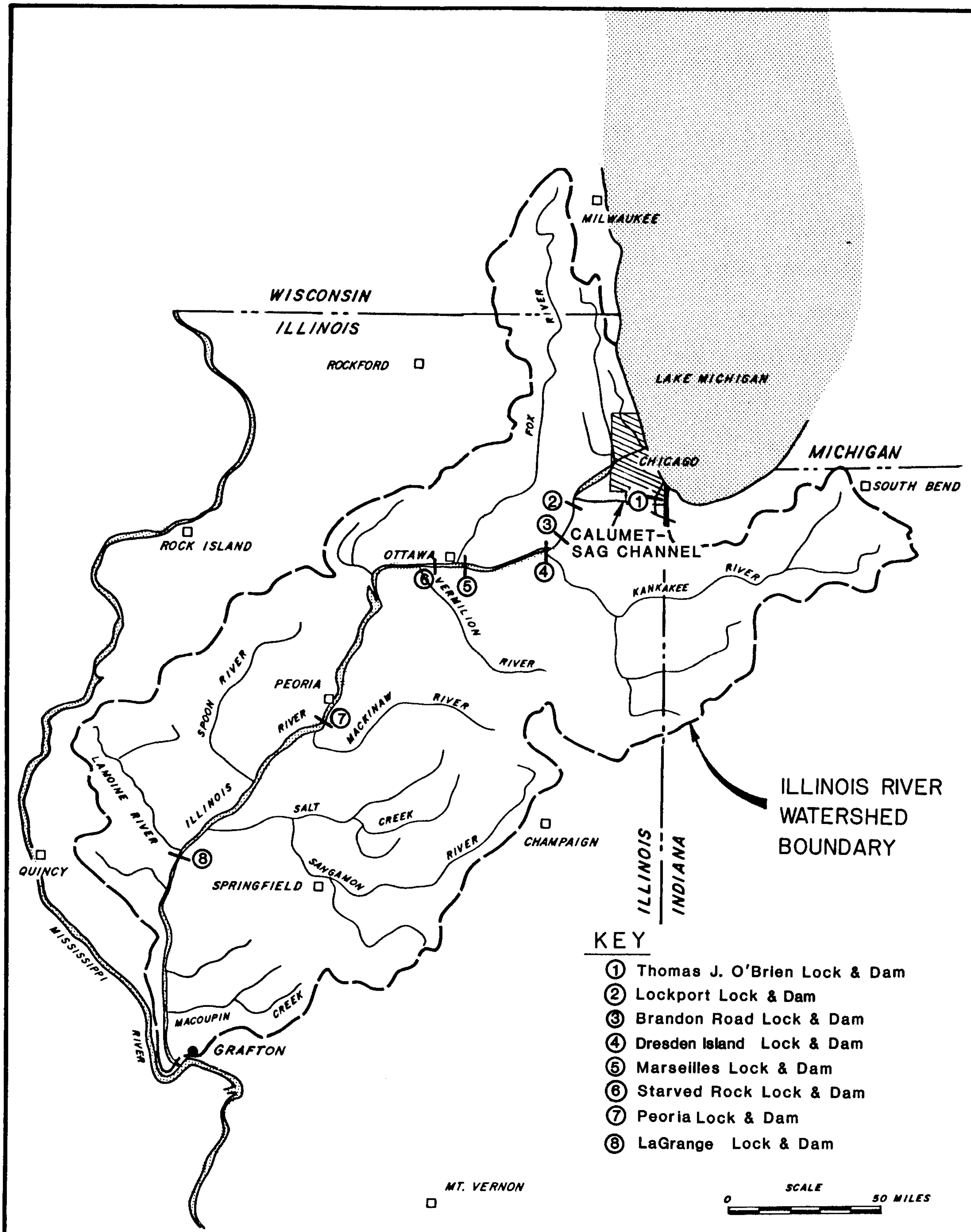
The Chicago Sanitary and Ship Canal was completed in 1900, replacing the Illinois and Michigan Canal as far as Lockport. The canal was constructed primarily for sewage disposal, secondarily for navigation. The completion of the Calumet-Sag Channel in 1922 diverted industrial wastes from the Calumet River into the Chicago Sanitary and Ship Canal above Lockport. Construction of the two canals made it possible to divert pollutants to the Illinois River system and away from Lake Michigan which provides Chicago's water supply. Upon completion of the Sanitary and Ship Canal, diversions progressively increased to a maximum annual average of about 10,000 cfs in 1928.

This diversion concept has been a controversial issue. In 1922, the State of Wisconsin successfully sought an injunction to bar the State of Illinois from diverting Lake Michigan water. However, in 1925, the U.S. Supreme Court overturned the injunction and diversion was allowed, subject to War Department conditions, at an average rate of 8,500 cfs in addition to domestic pumping. Other decrees were issued by the U.S. Supreme Court in 1930 and 1967 and again amended in 1980. The 1930 decree required the State of Illinois and the Metropolitan Sanitary District of Greater Chicago (MSDGC) to reduce diversion of water from Lake Michigan, in addition to domestic pumpage, according to the following schedule: (1) on and after July 1, 1930, an annual average of 6,500 cfs; (2) on and after December 31, 1935, an annual average of 5,000 cfs; (3) on and after December 31, 1938, an annual average of 1,500 cfs. As a result of this decree, the total diversion after 1938 was of the order of 3,100 cubic feet per second. The 1967 decree raised the maximum allowable total diversion to 3,200 cfs but added domestic pumpage quantities into this limit. The Calumet-Sag Channel was improved for navigation during the 1960s through to the deep draft Calumet Harbour and River on the south side of Chicago. The 1980 amendment left the maximum allowable total diversion at 3,200 cfs, but modified the method of accounting for this amount.

4.3.3 Description of the Present Diversion System

Diversion of water from the Great Lakes drainage basin occurs at Chicago, Illinois, through the Illinois Waterway to the Mississippi River and the Gulf of Mexico. The Illinois Waterway extends from the Mississippi River at Grafton, Illinois, (38 miles upstream of St. Louis, Missouri) to Chicago, Illinois, a distance of 326 miles, and has a natural drainage area of about 29,000 square miles. It provides a nine-foot depth navigation channel between the Great Lakes- St. Lawrence drainage basin and the Mississippi River (see Figure 4-3). The Illinois River forms the major part of the Illinois Waterway.

The Illinois Waterway is maintained by eight locks and dams which, except for the dam structure at Lockport, Illinois, are owned and operated by the Corps of Engineers. The dam structure at Lockport, the lock and controlling works at the mouth of the Chicago River, and a diversion structure at Wilmette, Illinois, at the junction of the Northshore Channel and Lake Michigan, are owned and operated by the Metropolitan Sanitary District of Greater Chicago. Table 4-1 gives some statistical data on the locks and dams along the waterway. The diversion of Lake Michigan water into the above described system occurs at the Wilmette Pumping Station, the Chicago River Lock and Controlling Works,



Location of Illinois Waterway System

Figure 4-3

Table 4-1
PERTINENT DATA ON THE LOCKS AND DAMS ALONG THE ILLINOIS WATERWAY

Lock and Dam[1]	Miles Above Mouth	Year Completed	Drainage Area (Square Miles)	Upper Pool[3] Elevation (Feet)
LaGrange Lock & Dam	80.2	1939	25,300	429.0
Peoria Lock & Dam	157.7	1939	13,900	440.0
Starved Rock Lock & Dam	231.0	1933	10,300	458.54
Marseilles Lock	244.6	1933	7,640	482.79
Marseilles Dam	247.0	1933	7,630	
Dresden Island Lock & Dam	271.5	1933	6,600	504.54
Brandon Road Lock & Dam	286.0	1933	1,450	538.54
Lockport Lock	291.1	1933	740[4]	577.48
Lockport Dam	291.1	1905	740[4]	
O'Brien Lock & Dam[2]	330.0	1965	0	
Chicago River Lock[2]	330.0	1938	0	
Wilmette Pumping Station[2]	-		0	

NOTES:

(1)These locks and dams are Federal structures with the exception of the Lockport Dam, Chicago River Lock, and Wilmette Pumping Station which are owned and operated by Metropolitan Sanitary District of Greater Chicago.

(2)These structures control the direct diversion from Lake Michigan at Chicago.

(3)Elevations based on MSL (1929 Adj.).

(4)673 square miles are Lake Michigan diverted watershed.

and the Thomas J. O'Brien Lock and Controlling Works, the location of which are shown on Figure 4-4, and at the 23 domestic water intake structures in Illinois. The width of the Illinois Waterway varies from 400 feet, upstream of LaSalle, Illinois, to 1,400 feet near the mouth at Grafton, Illinois, except through Peoria Lake where it expands to one mile wide. The natural drop in elevation of the Illinois Waterway in the 49 miles from the junction of the Kankakee and DesPlaines Rivers to the head of the alluvial valley at LaSalle, is about 53 feet. From LaSalle to Peoria, Illinois, a distance of 61.5 miles, the fall is only four feet; and from Peoria to the mouth of the waterway at Grafton, a distance of 162.6 miles, the fall is 28 feet.

Navigation is an important economic factor of the Illinois Waterway. The location of the waterway makes it a major conduit for the movement of agricultural and industrial commodities such as coal, petroleum, grain, sand and gravel. As the connecting link between the Great Lakes and the Mississippi River navigation systems, the waterway handled 47 million tons of commerce in 1976. All other modes of intercity freight transportation including railroads, trucks, pipelines and airlines, are also available in the basin. The population of the Illinois River basin totaled almost 10 million in 1970, with 83 per cent of the population being urban. The basin population is projected to exceed 15 million by 2020.

Manufacturing accounts for the largest percentage of total earnings in the basin, with agriculture being relatively inconsequential in the Chicago and Northwestern Indiana Metropolitan areas. However, agriculture is much more important in the basin outside these metropolitan areas, with about 70 per cent of the basin area utilized for agricultural production. The primary products are grain and livestock.

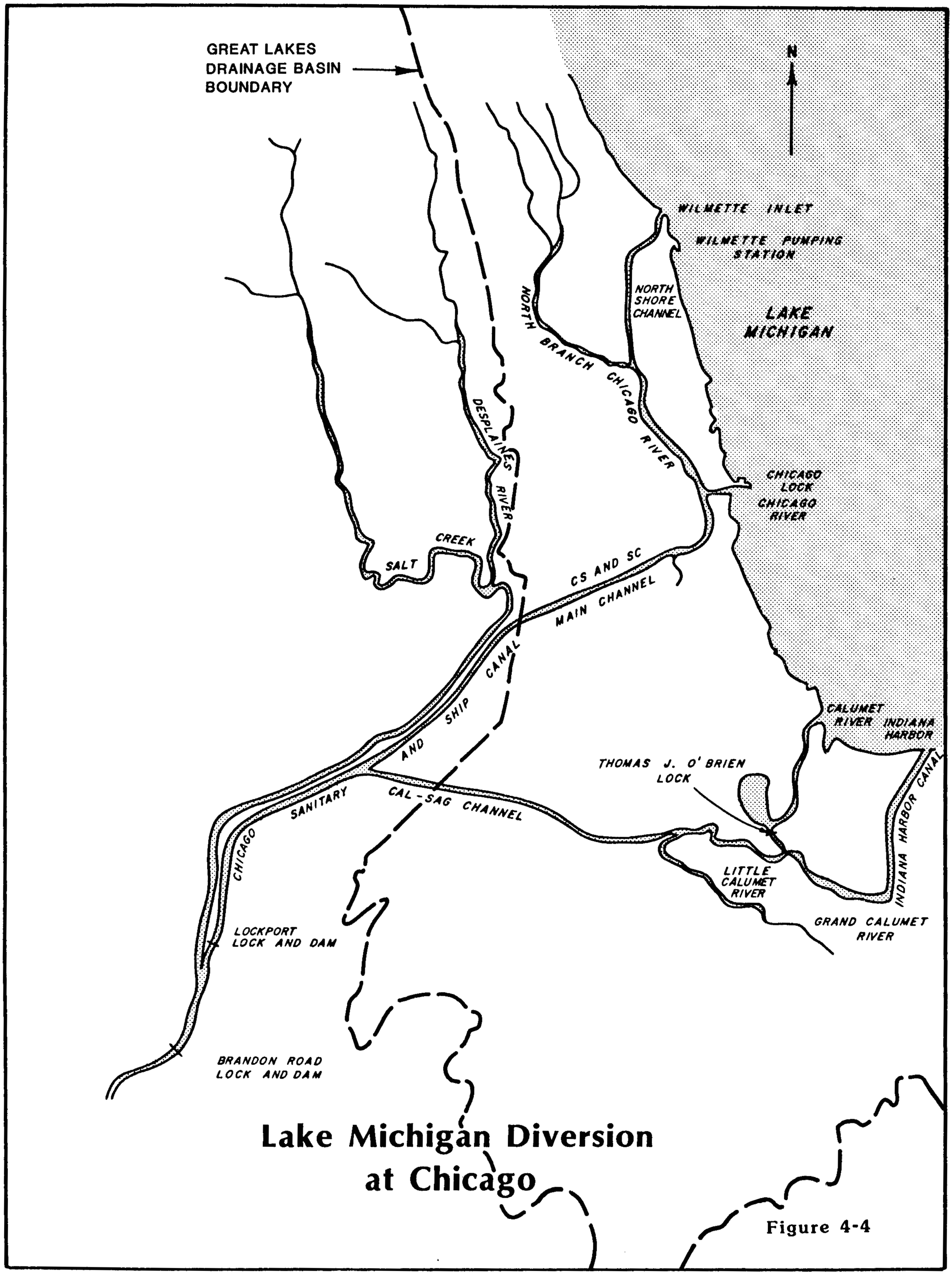
Two hydro-power generating facilities located at Lockport and Marseilles, Illinois, use Illinois River flows to drive units with a total installed capacity of about 15,500 KW.

The Illinois River valley is one of the most important areas for migrating waterfowl in the United States, and monetary expenditures by sportsmen are important to the economy of the basin.

Commercial fishing is insignificant today on the Illinois River. Recreational fishing, boating and associated activities are provided at state and local parks, forest districts, and conservation and recreational areas located along the river.

For the purpose of evaluation of impacts, the waterway has been divided into four reaches in different physiographic sectors, which are described as follows:

(a) Canal Reach. This reach extends for a distance of 41 miles from Lake Michigan to Brandon Road Lock and Dam, and includes the DesPlaines River from Brandon Road Lock to Lockport Lock; the Chicago Sanitary and Ship Canal to Sag Junction; and the Calumet-Sag Navigation Project, Part I, which provides a connection to the deep-draft project on Lake Calumet and the upper limit of Calumet Harbour via the Calumet-Sag Channel, the Little Calumet River and the Calumet River. An alternate route to Lake



Lake Michigan Diversion at Chicago

Figure 4-4

Michigan is also provided from Sag Junction to Chicago Harbour via the Chicago Sanitary and Ship Canal and the Chicago River. The waterway channels occupy a plateau eroded to Silurian bedrock during Pleistocene glaciation. The surrounding area is highly industrialized. Current velocity is greater in this reach than in the lower reaches. There is a substantial discharge of various urban effluents, causing water quality to be rather poor and creating unfavourable conditions for natural habitat. There are few desirable biological resources.

(b) Upper Valley Reach. This reach includes the Dresden Island, Marseilles and Starved Rock pools and extends for a distance of 55 miles. It lies between steep bluffs within a relatively narrow valley of the upper Illinois River. The river gradient is steep and water velocity is high. Land use is urban, industrial and agricultural. Water quality is affected by upstream discharges, augmented by additional industrial discharges. Biological resources are relatively poor. Aquatic and benthic communities are not diverse and the adjacent terrestrial habitat is of relatively low value.

(c) Mid-Valley Reach. This reach, which extends for a distance of 150 miles, includes the Peoria and LaGrange Pools. It is wider than the upper reach and contains many bottomland lakes, ponds and sloughs. Water velocity is slow, and the water quality is better than in the upper reaches. Land use consists of a mix of farming and urbanization. There are many duck clubs, and waterfowl hunting is very important. This reach contains the most valuable wildlife habitat and biological resources.

(d) Lower Valley Reach. This reach extends from the LaGrange Dam to Grafton, Illinois, a distance of 80 miles, and includes the Alton Pool of the Mississippi River. The physiography is similar to that of the Mid-Valley Reach, but the river is confined between levees. The current is slower than the Mid-Valley Reach and the water quality is better. Most of the floodplain is devoted to agriculture and wildlife habitat and natural biological resources are less extensive than in the Mid-Valley Reach.

4.3.4 Environmental Components of the Illinois Waterway

The environmental components of the Illinois Waterway are classified into four main groups: geographic, abiotic, biotic and anthropic. The principal characteristics of these groups are broadly described, as follows:

(a) Geographic Components. This group includes (1) land use, (2) ecosystems, and (3) special or sensitive areas. Land use ranges from highly urbanized and industrialized to agricultural. The locations of the land use types have been indicated in the previous discussion on project reaches. There are two major categories of ecosystems: terrestrial and aquatic. Terrestrial ecosystems include forest habitat, where bottomland forest tree species predominate. There are extensive bottomland forests along the waterway, which have both economic and wildlife habitat values. There is a substantial acreage of land devoted to agriculture. Also, another important upland ecosystem is the "moist soil ecosystems", which occur on mudflats and lakes, and provide food for waterfowl. Aquatic ecosystems consist of the river channel itself, marshes and backwater lakes which provide widely diverse conditions and habitats. There are twenty-three areas comprising about 800 acres which contain natural areas or are significant for other reasons.

(b) Abiotic Components. The abiotic components of the area are (1) atmospheric, (2) geologic, and (3) hydrologic. The waterway has a wide range of weather and temperature conditions. There are intense and frequent storms. Prevailing winds are westerly; air quality is variable, depending upon influences from urban and industrial areas. Pollutants are readily dispersed. The geologic features of the waterway have been determined by deposition, deformation and glaciation. There are good supplies of groundwater and mineral resources. Most of the soils are of the loess type. The general aspects of the hydrologic elements have been broadly discussed under "Description". Not yet mentioned, however, is the fact that sedimentation has had a significant influence on changing the character of the river.

(c) Biotic Components. The waterway contains much riparian vegetation which consists of bottomland hardwood forests. About three quarters of the original forest has been removed, but a substantial acreage of valuable forest still remains. The moist soil communities which occur on mudflats support annual vegetation which is valuable waterfowl food. Plant composition is highly variable. The marsh communities are dominated by perennial plant species. These are also important to wildlife. The waterway habitat support diverse populations of mammals, birds, reptiles, and amphibians. Aquatic communities have been severely disturbed by man's activities but still support a relatively diverse variety of vertebrates, invertebrates and plants. Some habitats of threatened and endangered species are found along the waterway.

(d) Anthropic Components. This category includes those elements of the human environment, such as archaeology, waterway history, commercial navigation, power generation, housing and commercial structures, bottomland agriculture and duck clubs. The Illinois valley is an extremely important archaeological area and contains a great many archaeological sites, some of which are highly significant, such as the Koster Site near Campsville, Illinois. The waterway has always been important as a transportation system for everything from canoes and steamboats to modern tugs and barges; in terms of commercial navigation, it is one of the most heavily used rivers in the United States. Two of the existing dams produce electric power. Although flooding has been a perennial problem, many people still reside in the floodplain. Bottomland soils are generally quite valuable for agriculture, especially when protected from flooding. Similarly, these soils are valuable for waterfowl refuge management and waterfowl hunting is popular along the waterway.

4.3.5 Amount of Diversion and Limitations

The existing Lake Michigan Diversion at Chicago is based upon a 1980 modification to the 1967 U.S. Supreme Court decree. Total diversions (including domestic pumpage) of Lake Michigan water into the Illinois Waterway by the State of Illinois and its municipalities are limited to an average of 3,200 cfs over a 40-year period. The average diversion in any annual accounting period shall not exceed 3,680 cfs, except that in any two annual accounting periods within a forty year period, the average annual diversion may not exceed 3,840 cfs as a result of extreme hydrologic conditions. For the first thirty-nine years, the cumulative algebraic sum of each annual accounting period's average diversion minus 3,200 cfs is not to exceed 2,000 cfs-years.

All measurements and computations required by this decree shall be made by the State of Illinois, or by the Corps of Engineers subject to agreement with and cost-sharing by the State of Illinois for all reasonable costs including equipment, using the best current engineering practice and scientific knowledge. All measurements and computations made by the State of Illinois are subject to periodic audit by the Corps of Engineers with an annual report on the measurements and computations issued by the Corps of Engineers.

Diversion from Lake Michigan consists of three components:

(a) Water supply taken from Lake Michigan and used for domestic and industrial purposes before being discharged into the river and canal system in the Chicago area as treated sewage;

(b) Runoff from a 673 square mile land area of the Michigan basin which once drained to Lake Michigan but now drains to the river and canal system; and,

(c) Water entering directly from Lake Michigan into the river and canal system in the Chicago area. This consists of:

(1) water required for lockages at the Chicago River Lock and the Thomas J. O'Brien Lock;

(2) leakages occurring at the Chicago River Lock, O'Brien Lock and Wilmette control structure;

(3) water taken in for dilution purposes at the Chicago River Lock, O'Brien Lock and Wilmette control structure; and,

(4) navigational make-up water, required to maintain navigation stages.

The breakdown of the diversion components listed as (a), (b) and (c) above, after year 2000, will be approximately 70 percent for domestic and industrial water supply, 21 percent for stormwater runoff from the diverted Lake Michigan basin and nine percent for direct diversion for lockages, leakages, discretionary dilution and navigational make-up water. Of the above items, only the amount under (c)(3), which is diverted directly from Lake Michigan, can be effectively controlled at all times. The quantity of water entering the river and canal system as treated sewage will vary depending on the amount of Lake Michigan water used for domestic and industrial purposes, and the amount of storm water reaching the treatment plants from the combined sewers. The quantity of storm water reaching the river and canal system is dependent on the precipitation over the watershed at any particular time. The water entering the river and canal system as treated sewage or storm water cannot be effectively stored in the rivers and canals, or elsewhere, for controlled release into the Illinois Waterway.

The flow chargeable to diversion is determined by taking the total flow measured at the Lockport control structure and deducting all inflows entering the canal system which are not chargeable to diversion. These non-chargeable flows are surface runoff from outside of the original watershed (approximately 67 square miles), domestic pumpage from wells not recharged by Lake Michigan, and domestic pumpage which originates in Indiana. These computations are made by the MSDGC and coordinated with the appropriate agencies of the State of Illinois under the general supervision and direction of the Chicago District, U.S. Army Corps of Engineers. There is no international control exercised under the Boundary Waters Treaty over this diversion.

4.3.6 P.L. 94-587 - Increased Lake Michigan Diversion at Chicago Demonstration and Study Program

Section 166 of the Water Resources Development Act of 1976 (P.L. 94-587) authorized the Secretary of the Army, acting through the Chief of Engineers, to carry out a five-year demonstration program of increasing the average annual Lake Michigan Diversion at Chicago above the present limit of 3,200 cubic feet per second (cfs) up to 10,000 cfs, and to conduct both a study and demonstration to determine the effects of the increased diversion on the levels of the Great Lakes, on the water quality of the Illinois Waterway and on the susceptibility of the Illinois Waterway to additional flooding. The study and demonstration were to investigate any adverse or beneficial impacts which result. A report is to be submitted to the U.S. Congress five years after authorization reporting on the results of the study and demonstration, and recommending whether to continue the authority or to change the diversion criteria.

The authorization specifies that diversion increases are to be effected incrementally and controlled to prevent adverse consequences on the Illinois Waterway, the Mississippi River, and the water levels necessary for navigation requirements in the St. Lawrence Seaway. No increased diversion is to be allowed when river levels approach or are predicted to approach bankfull conditions at the established flood warning stations on the Illinois River or the impacted portion of the Mississippi River. When the level of Lake Michigan is below its average level, the total diversion for the succeeding accounting year shall not exceed 3,200 cfs on an annual basis. The average level of Lake Michigan is to be based upon the average monthly level for the period 1900 to 1975. The program was to be developed by the Chief of Engineers in cooperation with the State of Illinois and the MSDGC and be implemented by the State of Illinois and MSDGC under the supervision of the Chief of Engineers.

No physical demonstration program was carried out because of insufficient funding and time constraints. Effects of various diversion rates and operational plans will be determined through computer model simulations. These simulations will provide adequate information for decisions on future actions concerning diversion criteria modifications.

As a result of studies conducted to date under this program, it has been determined that, giving consideration to bankfull conditions, it would be physically possible to discharge up to an annual average of 8,700 cfs during periods of high water supply on the Great Lakes.

The study requires one full year of work effort for completion. At this time no funds are in the President's budget for Fiscal Year 1982 (1 October 1981 - 30 September 1982). The Corps of Engineers plans to complete the study and report in FY82 if funds are provided by Congress.

4.3.7 Hydrologic Effects of Existing Diversion

The Lake Michigan Diversion at Chicago has modified the hydrologic regime of both the Great Lakes system and the Illinois River. The diversion is in effect an additional tributary which has been added to the Illinois River with a diverted watershed area of 673 square miles and an annual minimum uncontrollable baseline flow of 2,880 cfs which will increase to 3,099 cfs after the year 2000. During severe precipitation events over the diverted watershed, maximum peak flows of up to 34,000 cfs occur. This added flow raises water levels on the lower Illinois River. The diversion has affected the Great Lakes system by increasing the outflow capacity of Lakes Michigan-Huron and decreasing supplies to the downstream lakes by the amount of the diversion and thereby reducing lake levels. Under plan 1977, there is also a small effect on Lake Superior levels as a result of this diversion.

4.4 Welland Canal

4.4.1 General

The Welland Canal is a deep-draft, man-made navigational waterway, totally within Ontario, Canada, which joins Lake Erie with Lake Ontario across the Niagara Peninsula (see Figure 4-5). It is the route for ocean-going vessels to gain access to Lake Erie and the upper lakes, bypassing the falls and rapids of the Niagara River which once presented the major obstacle to an uninterrupted water route.

4.4.2 History

The original Welland Canal was built in 1829, between Port Dalhousie on Lake Ontario and Port Robinson on the Welland River, to allow navigation between Lakes Erie and Ontario. Prior to 1881 the small water requirement of the Canal, approximately 85 cfs, was supplied through a feeder canal from the Grand River at Dunnville, Ontario, a tributary to Lake Erie. In 1881 the summit reach of the canal was cut through at Lake Erie level and the Lake Ontario end of the canal reconstructed. The improved canal required additional water and by 1887 the diversion amounted to 400 cfs. Between 1887 and 1898 the old canal was adapted for power purposes and by 1898 the total rate of diversion had reached 1,000 cfs. As hydro-power units were installed in the No. 1 plant at DeCew Falls and fed from the Welland Canal, the total diversion grew from 1,100 cfs in 1901 to 1,500 cfs by 1908 and to 2,000 cfs by 1913.

The present Welland Canal has been greatly improved since it was built between 1913 and 1932. By 1933, the total diversion was 2,500 cfs. There was little change during the remaining years of the thirties. However, to meet the power requirements due to World War II, supplementary flow was provided and the total diversion in 1942 reached

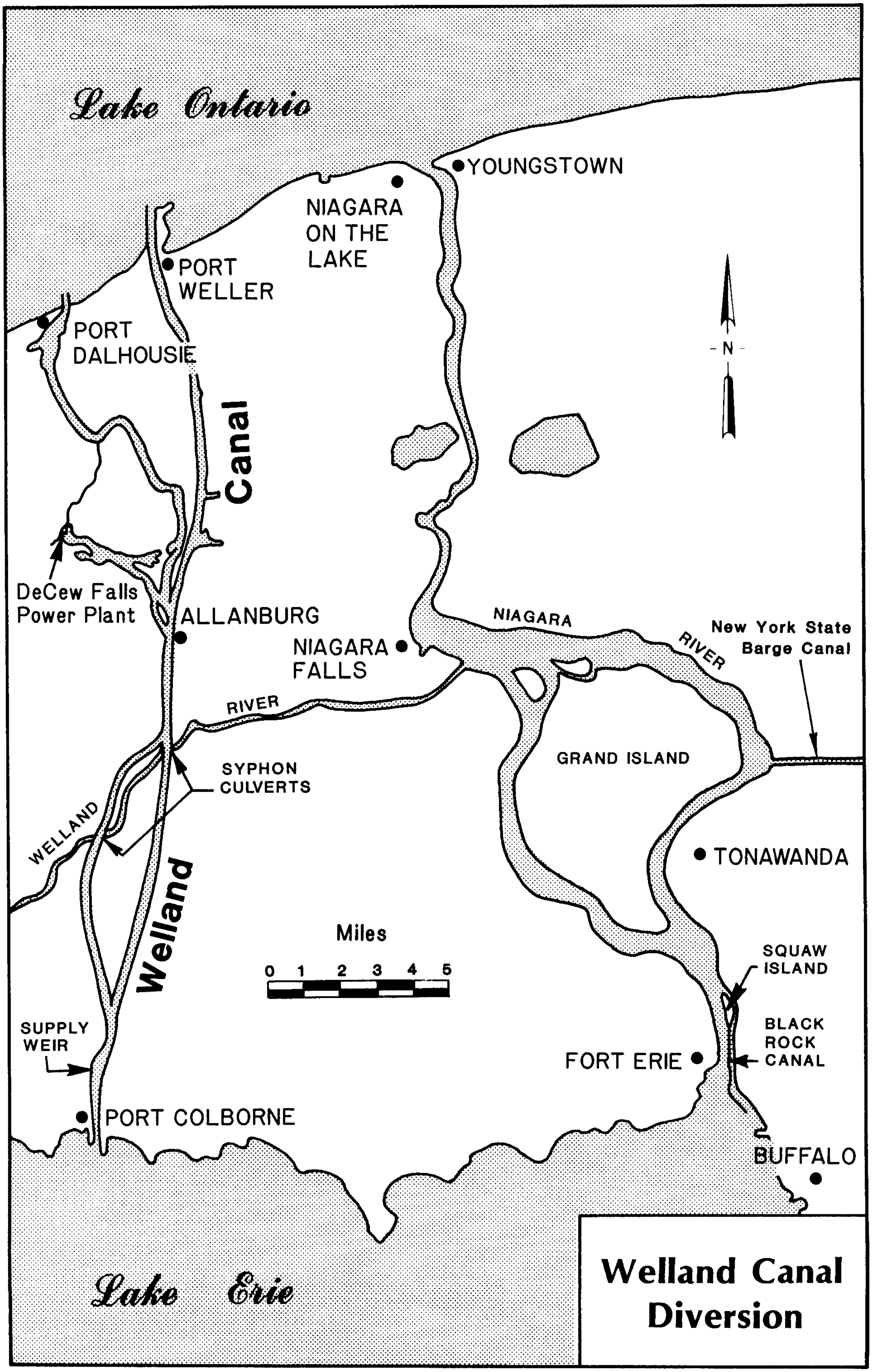

Lake Ontario
YOUNGSTOWN
NIAGARA
ON THE
LAKE
PORT
WELLER
PORT
DALHOUSIE
Canal
N
DeCew Falls
Power Plant
ALLANBURG
NIAGARA
FALLS
NIAGARA
RIVER
New York State
Barge Canal
RIVER
GRAND ISLAND
SYPHON
CULVERTS
WELLAND
Welland
TONAWANDA
Miles
0 1 2 3 4 5
SQUAW
ISLAND
BLACK
ROCK
CANAL
SUPPLY
WEIR
FORT ERIE
PORT COLBORNE
BUFFALO
Lake Erie
Welland Canal
Diversion

Figure 4-5

3,200 cfs. The No. 2 DeCew Falls power plant was installed during the period 1943 to 1947, and by 1951 the total diversion was at a maximum rate of 7,400 cfs.

4.4.3 Description of the Present Canal

The Welland Canal is a deep-draft man-made waterway joining Lake Erie with Lake Ontario across the Niagara Peninsula. The Canal was constructed to allow commercial shipping to transit between Lakes Erie and Ontario. The canal lies wholly within the province of Ontario, and since 1959 has been operated by a Canadian crown corporation, the St. Lawrence Seaway Authority, as an integral part of the St. Lawrence Seaway system.

The canal runs in a nearly straight south-to-north direction between Port Colborne on Lake Erie and Port Weller on Lake Ontario, a distance of about 27 miles. The 327-foot difference in water levels between Lakes Erie and Ontario is overcome by eight lift locks spaced along the canal. Factual information concerning these locks is given in Table 4-2. The seven lower locks are located within eight miles of Port Weller, and have an average lift of 46.5 feet each. The eighth lock, at Port Colborne, serves as a shallow-lift guard lock at the upper end of the canal.

The present Welland Canal is a modified version of the fourth Welland Canal (Welland Ship Canal), which was constructed beween 1913 and 1932. Improvements have been made at various locations along the canal to enhance its efficiency. The latest major improvement was completed in 1973 with the complete upgrading and re-routing of nine miles of the canal away from downtown Welland. Most of the canal's features and equipment, however, have remained as originally installed.

Commodity traffic through the canal has increased steadily over the years. In 1932 about 8.3 million tons passed through the canal in 5,712 transits; by 1979 the traffic reached 73 million tons in 6,547 transits. About 75 percent of this traffic is U.S. and Canadian interlake trading in iron ore, coal, limestone and grains. The remainder is fuel oils, iron and steel and other domestic lakes traffic, as well as cargo destined for or arriving from overseas ports.

Until 1932 the largest vessels transiting the canal were less than 261 feet in length and carried less than 3,000 tons of cargo. The completion of the Welland Ship Canal opened the route to the 13,000-ton bulk freighters, 600 feet in length, which previously had been confined to Lake Erie and above. It also induced the construction of even larger vessels; many over 700 feet in length began to appear. Today, 50 percent of canal traffic is carried in "seaway-sized" lakers, 730 feet in length, 76 feet in breadth and carrying 28,000 tons of cargo. The seaway-sized laker is the largest vessel presently permitted to enter the canal. The limiting feature is the size of locks, as shown in Table 4-2. The maximum allowable vessel draft in the canal is 26 feet. This is limited by the controlling depth (27 feet) of the canal prism. Although it is impossible to pass larger vessels through the canal, some future gains in throughput are expected to be achieved by way of operational improvements. The Seaway Authority expects, however, that all possibilities for major gains in throughput will be exhausted by the end of the 1980s, when capacity will be reached at about 34 transits per day, or 90 million tons annually.

Table 4-2
WELLAND CANAL LOCK DATA

Lock	Normal Lift, Ft.	Usable Length of Chamber, Ft.	Usable Width of Chamber, Ft.	Minimum Depth at Sill[(2)], Ft.
1	46.0	730	76	30
2	46.5	730	76	30
3	46.5	730	76	30
4	47.9	730	76	30
5	47.9	730	76	30
6	43.7	730	76	30
7	46.5	730	76	30
8	2.0-11.0[(1)]	1148	76	30

Notes: (1) Depending upon the prevailing level of Lake Erie.
(2) The controlling channel depth is 27 feet.

The Welland Canal's success as a commercial transportation artery has led to substantial industrial development and urban settlement in its vicinity. A line of urban communities exists along the canal, some centered on the operation of the canal itself; others taking advantage of cheap transporation, abundant water supply or the opportunity to service shipping and canal needs. The attractions of a canal-side location are extended by ready accessibility to road and rail facilities, as well as cheap hydro-electric power.

Thus the Welland Canal Diversion serves several purposes, apart from navigation. Water for power generation at Ontario Hydro's DeCew Falls generating stations (located about three miles west of the canal), is diverted from the canal at Allanburg. Diversions of canal water for industrial cooling and industrial and municipal water consumption occur at numerous points along the canal. For example, a portion of canal water is diverted into the Welland River to maintain its water quality, and induce flow in the old canal channel in the city of Welland. The present total diversion down the Welland Canal is about 9,200 cfs, calculated on a mean annual basis. More detailed descriptions of the uses of canal water and the method of operating the canal to satisfy these needs are given in the following paragraphs. Also included are descriptions of the physical capacities and practical operating limitations of the various systems presently using canal water, including the canal's main lock and weir system. The summation of the capacities of each part of the canal facility will give an approximation of the absolute capacity of the canal with respect to diversion of Lake Erie water. Consideration of the practical operating limitations gives a better indication of the maximum diversion that is ever likely to occur without major modification to the facility.

Hydraulic Operations Within the Canal

Water enters the canal through a supply raceway, or channel, and through Lock 8 at Port Colborne. The main supply to the canal (which in recent years has been about 9,000 cfs on a mean annual basis) enters through the raceway, which is completely controlled by a weir. The intake through Lock 8 is the result of navigation lockages. This averages about 175 cfs during the navigation season. The lock passes no water after navigation ceases.

Supply Raceway: The present supply weir and equipment constitute the original installation completed in 1932. The weir consists of ten tainter gates, 15 feet wide by 14 feet high each. The gates work in two banks of five gates each. Each bank can be adjusted individually. Gate settings are made remotely from the Lock 8 control tower.

The principle behind the operation of the supply weir is to maintain the water level in the "summit reach" or "long reach" of the canal, i.e., the section between Lock 8 and Lock 7. This level is maintained at 568.0 feet (IGLD) at Lock 8, which provides a depth of 30.8 feet over the sill of Lock 8, and 30 feet over the sill of Lock 7 (the difference is due to the hydraulic gradient of the canal), to meet the requirement for safe navigation. The seemingly simple feat of maintaining the summit level is in fact considerably complicated by a host of factors and limitations which must be taken into account when making inflow adjustments. These factors include fluctuating water demand downstream, the presence and mode of activity of shipping at various critical points in the canal, the ever-changing level of Lake Erie, flow velocity restrictions at various points and water levels at key points in the canal, wind effects on the water surface profile in the summit reach, bank erosion concerns and so on. In this context then, the present operating mode, with respect to the water levels regime in the canal, can be considered to be "bankfull". This regime must remain intact if navigation and other canal functions are to continue. Any increase in levels would cause spillage over lock gates, coping walls and docks, and would flood considerable acreage around lock pondage basins ('pondage' is explained later in this section). Recently an automated and computerized control system was installed to assist the weir operator by providing instant analyses and information concerning conditions in key areas. However, in the final analysis, safe and efficient operation of the canal's intake still depends largely on the capability of an experienced operator.

The gate opening required to achieve a desired intake flow through the supply weir is determined using a weir calibration curve and flow equation, which convert the head on the weir and the gate opening to weir intake. In practice, the gate opening is adjusted until the desired flow is obtained. The intake flow is calculated and displayed continuously by computer for the benefit of the weir operator. The calculated flow is also recorded continuously. Also displayed and recorded continuously for the weir operator are the levels of Lake Erie and the supply channel below the weir. The gauges for these levels, which are the ones used to calculate flow through the weir, are located just upstream and downstream of the weir. The weir calibration was last checked in 1966-67. It showed very little difference from the original calibration done in 1933.

Under a head of one foot (that is, a difference of one foot between the water levels of Lake Erie and the supply channel below the weir) the supply weir is capable of passing about 12,000 cfs, which is more than the current canal requirement. Under greater head the weir can pass more water; for instance, with a three-foot head it can pass about 21,000 cfs. Since the level of Lake Erie (and thus the head on the weir) fluctuates continuously, frequent gate settings are required to maintain the desired flow through the weir. When the level of Lake Erie is very low, reducing the head on the weir to less than one foot, it becomes impossible to maintain the full required intake into the canal. During these periods, the flow to DeCew Falls is cut back in order to supply navigation requirements. If there is no head, or a negative head develops at the weir, navigation may be suspended while the condition exists. However, if the zero-head situation persists for more than a few days; other precautions are taken, depending on the magnitude of the drop in water level in the canal. This would include reducing the allowable shipping draft in the canal.

The rate of intake into the canal through the supply weir is governed mainly by velocity considerations, both in the supply channel, in which the weir is located, and in the main ship channel. Too great and too sudden a change in intake velocity at the entrance to the supply channel has drawn vessels onto the shoals in that area. Downstream of the weir, high velocity flows in the supply channel cause several serious problems. First the high cross-currents generated at the point of confluence with the main shipping channel are dangerous and disruptive to navigation; when the supply channel flow exceeds about 9,000 cfs, the resulting high current velocities produce a decrease in water depth (a hydraulic phenomenon) which becomes of serious concern to vessels berthed at the Robin Hood wharves on either side of the downstream end of the supply channel. Furthermore, any sudden change in velocity in the channel will cause a sudden, dangerous shift in vessels at these berths.

It is frequently necessary to shut down the weir to reduce velocity in the supply channel and in the main ship channel when vessels are tieing-up at the Lock 8 approach walls. Similar current velocity reductions are also required to assist in vessel passing manoeuvres when initial velocity is high, and to reduce critical velocities in the restricted portions along the canal. Many otherwise simple manoeuvres become disproportionately difficult (even for an experienced mariner) in the presence of high currents because of the hull pressures generated and loss of steering.

Another operational constraint in setting canal flow is the effect of high current velocity on bank stability in the supply channel and other locations along the canal. Even though the supply channel is protected by boulders and bedrock in places, it is difficult to control erosion. In recent years, the high velocity flows in the canal have aggravated the erosion problem, increasing the incidence of bank slumping and flushing boulders two feet and more in diameter from the bank walls of the supply channel out into the main ship channel. Through experience, the Seaway has found that this type of problem is minimized when sustained flows are kept below about 9,000 cfs. High currents in the main navigation channel itself are also a cause of erosion and bank slumping. There is evidence of this problem at various points along the canal.

Only through experience is the operator of the supply weir able to balance the numerous criteria and restraints associated with keeping the canal supplied with water. He must keep water levels constant throughout the canal; he must keep Ontario Hydro and other users supplied with uninterrupted supplies; at the same time, he must keep current velocities throughout the canal favourable to safe navigation. In spite of his efforts, however, erosion occurs, incidents happen and Ontario Hydro occasionally temporarily loses some or all of its allotted supply.

Lock 8 Intake: The amount of water entering the Welland Canal through Lock 8 is calculated from the difference in head above and below the lock at the time of lockage, the corresponding lock intake and the number of lockages. Water level gauges are situated above and below the lock for this purpose. The gauge below the lock is the same one used to monitor the water level in the summit reach. The amount of water entering the canal is the sum of the intakes through Lock 8 and the previously described supply weir at Port Colborne; it is calculated and recorded continuously and summarized daily, monthly and annually on records which date back to 1952. Figure 4-6 gives the total annual mean flow through the Welland Canal since 1860. These flows were obtained from the St. Lawrence Seaway Authority, and the report "Lake Erie Outflow 1860-1964, with addendum 1965-1975", by the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data, June 1976.

Uses of the Canal Water and Diversion Rates

Also included in the summary records are the amounts of the various diversions and uses of canal water which occur below Lock 8 and the supply weir. A typical mean annual distribution of canal water is shown schematically in Figure 4-7. About 70 percent of the water entering the canal is diverted out again at Allanburg for power generation. Ontario Hydro has two raceways leading from the canal to their Lake Gibson pondage area which feeds two generating stations at DeCew Falls. Intake into the raceways is completely controlled by weirs. The water diverted for the DeCew plants is not used for navigation, and is not returned to the canal; it is discharged directly into Lake Ontario through Twelve Mile Creek.

Between 1952 and 1978 the total diversion to DeCew Falls fluctuated around a mean value of about 6,000 cfs (see Figure 4-8). During that period, Ontario Hydro had a purchase agreement with the Seaway Authority for a maximum supply of 6,400 cfs on an annual mean basis. The full 6,400 cfs was rarely diverted for a variety of reasons including plant shut-downs, canal intake reductions for maintenance work and during periods of low Lake Erie levels. In the latter case, when Lake Erie levels are low, intake into the canal may be reduced (as explained earlier); after municipal, industrial and navigation water requirements (which take precedence) are satisfied, the water remaining for power generation may be less than that provided for in the purchase agreement. Ontario Hydro's current contract, in effect since 1978, allows for a maximum of 6,887 cfs as an annual mean. Under the agreement, Ontario Hydro can receive up to 7,550 cfs per month during the non-navigation season, and about 6,670 cfs per month during the navigation season. It is estimated that about 7,550 cfs is the combined maximum that can flow through the two raceways to DeCew. The estimated capacities of the raceways are about 1,500 cfs and 6,050 cfs.

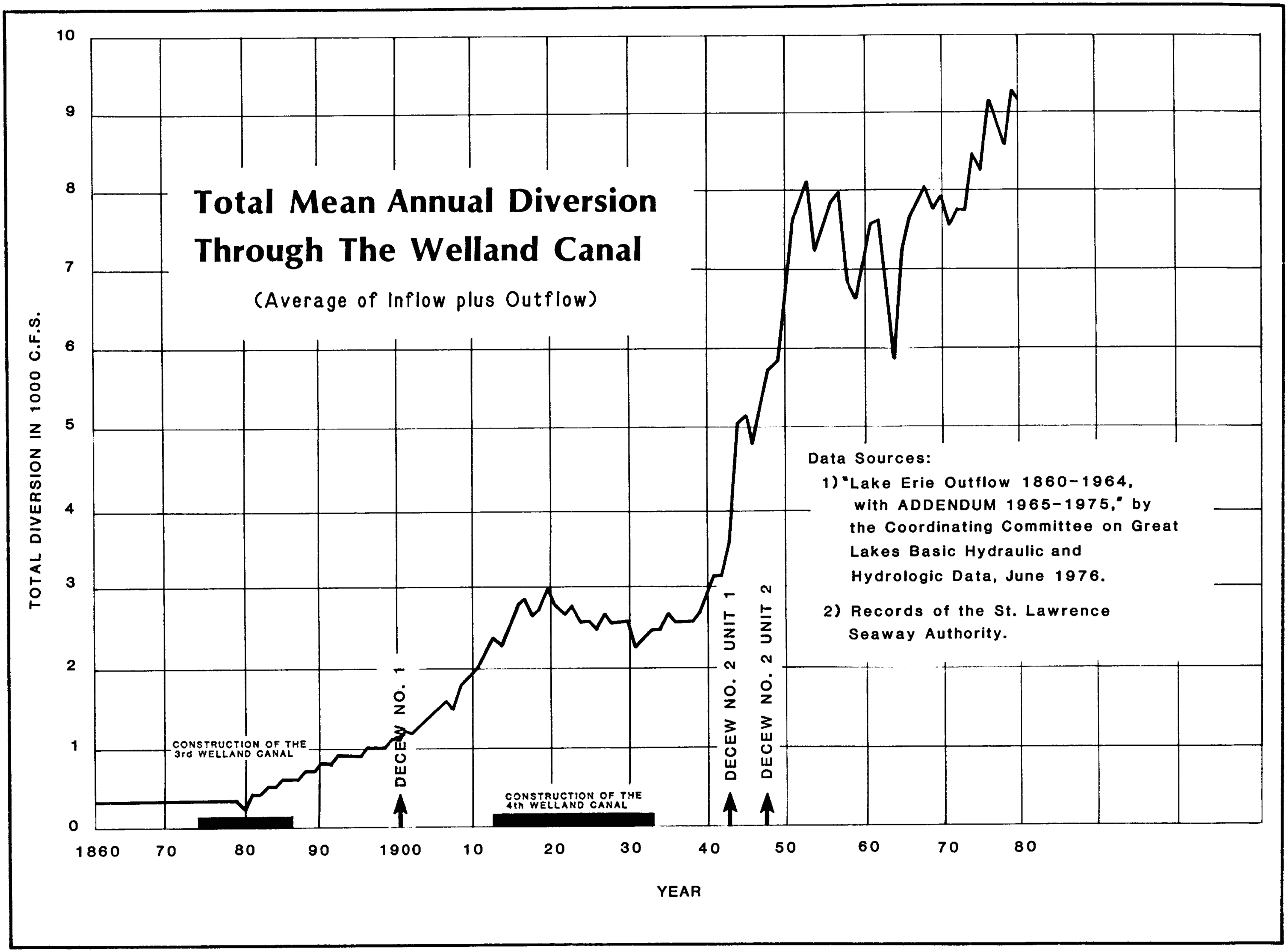
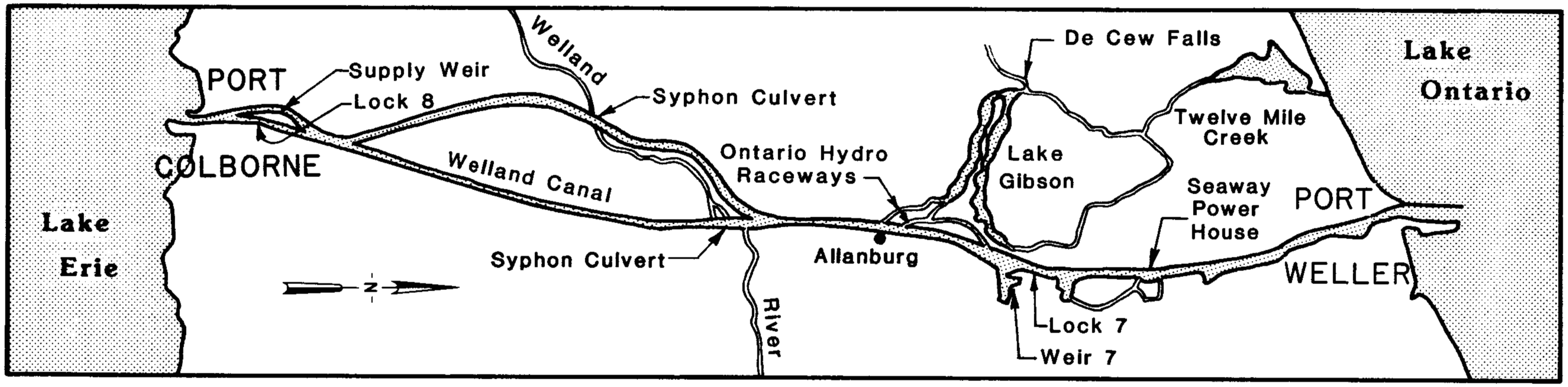

Total Mean Annual Diversion Through The Welland Canal
(Average of Inflow plus Outflow)
TOTAL DIVERSION IN 1000 C.F.S.
0
1
2
3
4
5
6
7
8
9
10
1860
70
80
90
1900
10
20
30
40
50
60
70
80
YEAR
CONSTRUCTION OF THE 3rd WELLAND CANAL
CONSTRUCTION OF THE 4th WELLAND CANAL
DECEW NO. 1
DECEW NO. 2 UNIT 1
DECEW NO. 2 UNIT 2
Data Sources:
1) "Lake Erie Outflow 1860-1964, with ADDENDUM 1965-1975," by the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data, June 1976.
2) Records of the St. Lawrence Seaway Authority.

Figure 4-6



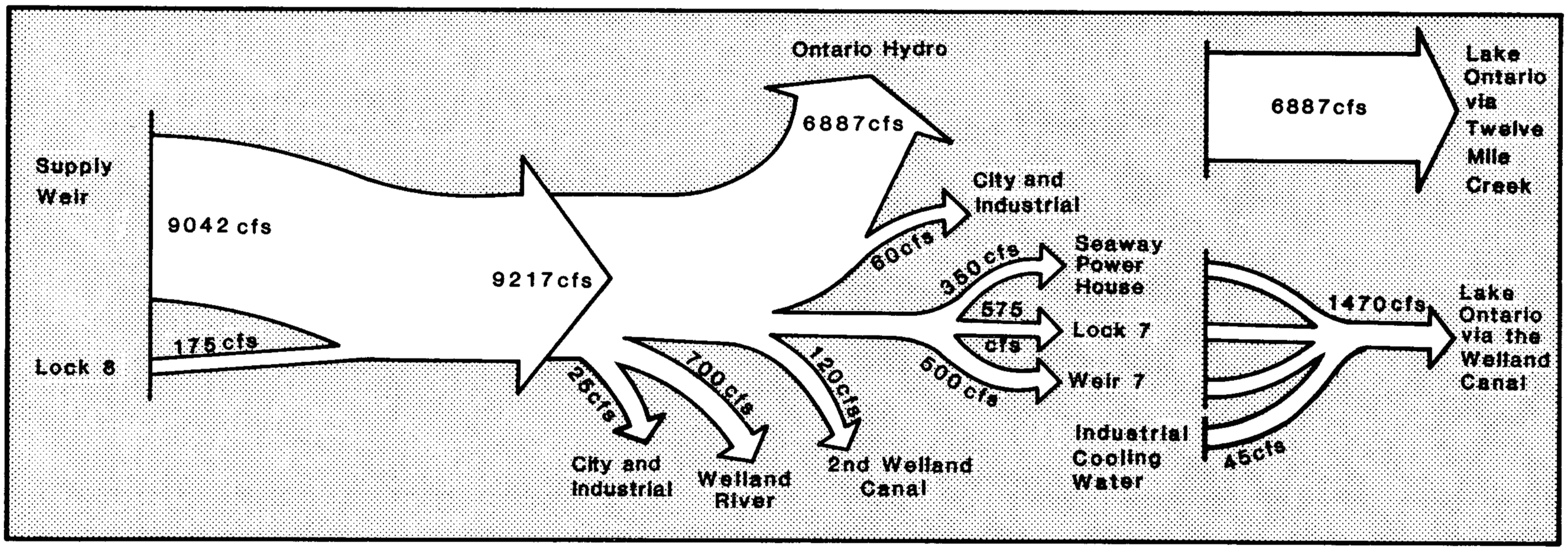
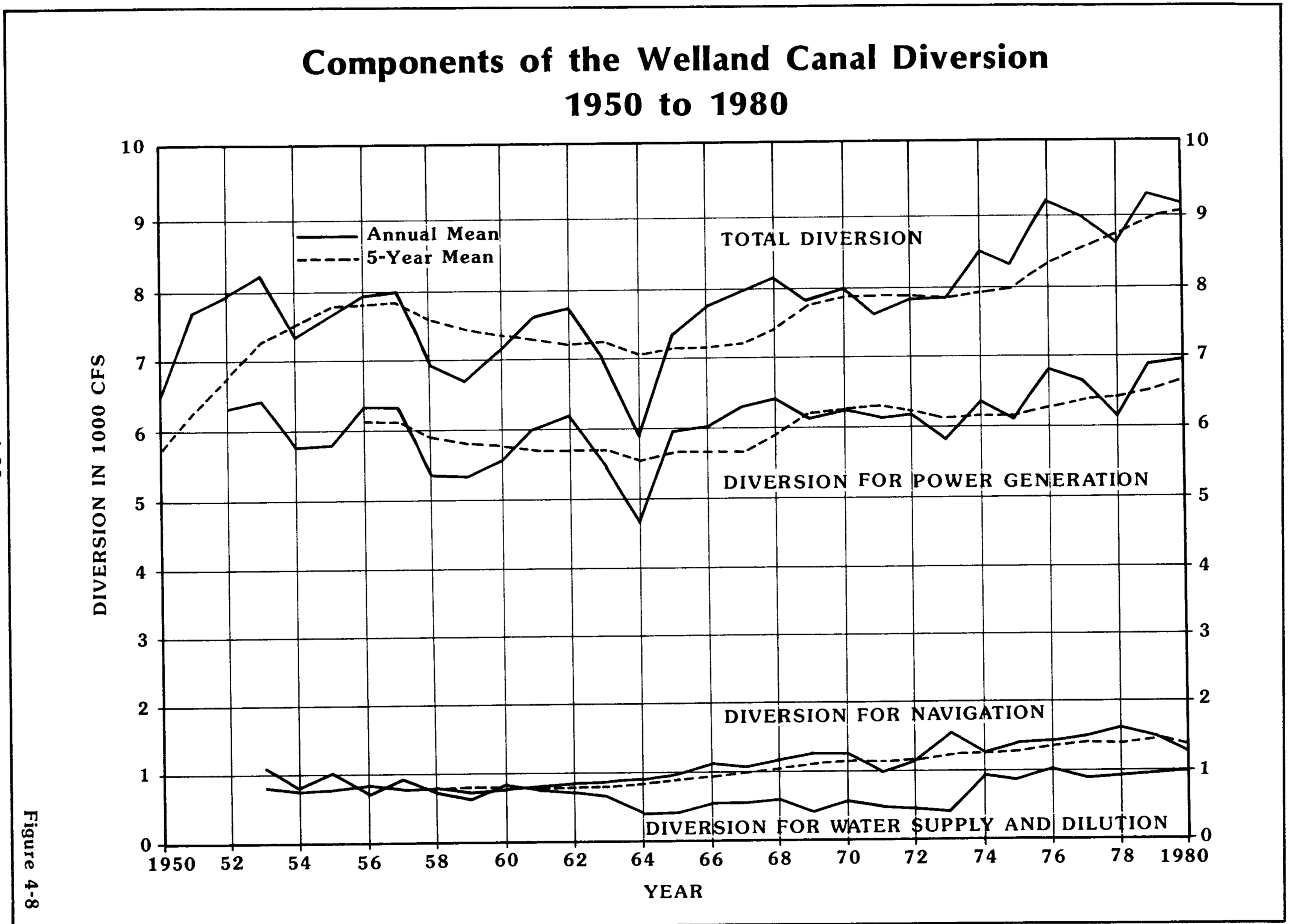


Figure 4-7

Typical Mean Annual Distribution of Welland Canal Waters



Components of the Welland Canal Diversion
1950 to 1980
Annual Mean
5-Year Mean
TOTAL DIVERSION
DIVERSION FOR POWER GENERATION
DIVERSION FOR NAVIGATION
DIVERSION FOR WATER SUPPLY AND DILUTION
DIVERSION IN 1000 CFS
YEAR
1950
52
54
56
58
60
62
64
66
68
70
72
74
76
78
1980
0
1
2
3
4
5
6
7
8
9
10

Figure 4-8

The second largest user of canal water is the St. Lawrence Seaway Authority, which requires water for navigation and power generation for the canal's navigation equipment. During the regular navigation season, lockages and lateral and hydraulic assists require about 1,100 cfs (for a seasonal average of about 24 ship transits per day). This figure varies depending on the level of shipping activity. During peak periods, when there may be as many as 30 transits per day, the average monthly requirement may be as high as 1,400 cfs. When the canal reaches traffic capacity, estimated to occur around the year 1990, the average number of transits per day during the navigation season will be about 30 and the maximum number of transits achievable in a day will be about 34; the consequent average water requirement will be about 1,400 cfs with peak requirements of 1,600 cfs.

An additional factor which could affect the annual diversion rate through the canal is an extension of the navigation season from its current nine months to nine and one-half months, as has been considered for the entire St. Lawrence Seaway. However, it has been estimated that such an extension would have an almost negligible effect on the annual mean diversion for the following reason. Under present operations, when navigation ceases in the fall, a large portion of the flow used by navigation is transferred to Ontario Hydro for power generation. As explained earlier, the maximum flow in the canal is restricted and navigation water requirements are deducted first. Therefore, during an extended navigation season, the transfer of flow to the power plants would simply be delayed by two weeks until navigation ceased. Because navigation during those two weeks would use slightly more water than would have otherwise been transferred for power generation, the net result is a minimal increase in the total annual diversion.

Each lock, or set of locks, in the Welland Canal is equipped with a by-pass or "waste" system which will pass water around the lock. These by-passes are controlled by weirs and are used to replenish downstream pondage areas. The pondage acts as a "surge tank" to prevent sudden large fluctuations in water level on the main ship channel as a result of lockages. Via the by-pass system, water can pass directly from the summit level above Lock 7 to the pondage for the flight lock system, Locks 6, 5 and 4. From the flight lock pondage it can continue on to the pondage for Lock 3, if necessary, without entering the ship channel. The flow between pondage areas is controlled by weirs. At Locks 3, 2 and 1 the by-pass weirs are located adjacent to the locks in the ship channel, and "spilled" water passes along the ship channel. The capacity of the by-pass system is set by the capacity of the weir for Lock 7, which is about 1,000 cfs. During the navigation season about 500 cfs are passed through the by-pass system for pondage water replacement. This water is used for lockages, lateral and hydraulic assists, and is included in the 1,100 cfs referred to above. This leaves a maximum reserve capacity of about 500 cfs for the system. As another 100 cfs or so will be needed for navigation in the future, the future ability of the system to draw additional water from Lake Erie will be 300 cfs to 400 cfs. However, in practical terms, this additional flow could not take place because of an adverse effect on navigation. The Seaway Authority has found that vessel manoeuvrability in the vicinity of Locks 3, 2 and 1 is dangerously impaired when the flow through the waste weirs is above 600 cfs.

The Seaway's power generation plant is located beside Lock 4. Water is taken from the canal above Lock 7 and fed by penstock to the power house. The water is returned to the canal below Lock 4 for re-use downstream. The plant presently draws about 350 cfs, both summer and winter. The maximum intake the plant can handle is about 550 cfs.

A plot of the total annual mean diversion of canal water for navigation for the period 1950 through 1980 is shown on Figure 4-8. Included are quantities for lockages, lateral and hydraulic assists, Seaway power generation and pondage.

The third largest usage of water from the canal is for water quality enhancement. About 700 cfs of dilution water is diverted from the canal year-round at the City of Welland. About 150 cfs of this is diverted by the Welland Waterworks Department to dilute sewage entering the Welland River. Another 525 cfs is drawn from the canal through holes drilled through the roof of the old Welland River syphon culvert in the abandoned ship channel at Welland. This diversion serves two purposes. One is to induce flow in the abandoned ship channel to prevent stagnation, as the only flow in the channel was cut off by causeway construction in 1973. Because this water ultimately enters the Welland River, the other purpose is to aid dilution. About 25 cfs is also diverted from the Welland Canal to the Welland River at Port Robinson and an additional small diversion of about five cfs is made from the canal into Lyons Creek, south of Welland, to replace flows in the creek which were cut off by the canal at Lyons Creek crossing. No increase in dilution water requirements is foreseen.

About 200 cfs are drawn from the system at various locations (e.g. Welland, Thorold, St. Catherines) for industrial cooling and other industrial and municipal uses. The amounts of these uses are controlled by a series of guidelines. Most of the cooling water is returned to the system. There are no known plans for major increases in industrial cooling or industrial or municipal consumptives uses.

Figure 4-8 shows the total Welland Canal diversion and its components and how they have varied since 1950. As previously discussed, water for navigation, water supply and dilution take precedence over water made available for power generation. Hence, as a result of the gradual increase in water needed for navigation and the marked increase in water supply needs (which began about 1973), there is less water available for power generation in 1980 than if these values had remained at pre-1970 level. It is estimated that this increase has reduced the water available for power generation in the order of 250 cfs. In addition, the table below indicates that the future needs of these interests could further increase. If this occurs there would be a further reduction in water available for power generation in both the Welland Canal and Niagara River.

All of the uses and routings of canal water have been described. Assuming navigation in the canal will continue as projected, the following summation of the ultimate navigation water requirement plus the maximum requirements for all other uses gives some indication of the theoretical maximum capacity for sustained diversion of Lake Erie through the Welland Canal.

	Theoretical Maximum Flow in cfs
Navigation (lockages, assists)	1,600
Seaway Power	550
Ontario Hydro Power	7,550
Dilution	700
Additional Capacity at "Waste" Weirs	400
Water Supply	200
	11,000

However, as already discussed, 11,000 cfs could not be sustained in the canal as it exists. Also, the Seaway Authority has found that the "most desirable" maximum sustained flow is about 9,000 cfs. However, due to a recent increased demand for water by Ontario Hydro, the Seaway has decided to accept the penalty of higher flows, up to about 10,000 cfs during peak-demand months. The penalty is increased maintenance of canal banks, more dredging and greater inconvenience to shipping. With 10,000 cfs as the maximum acceptable monthly mean flow, the maximum annual mean flow will likely never exceed about 9,400 cfs or 9,500 cfs. There are several reasons for this. The canal is closed to navigation for three months of the year and the supply weir must be shut down occasionally during the year to assist in canal maintenance and vessel manoeuvring. Also, the summit level must usually be lowered a few feet during the winter months to allow maintenance work. At such times the flow to DeCew Falls will be reduced. Occasional shutdowns for repair and maintenance at the DeCew plants will further reduce the amount of water which can be used there.

4.4.4 Environmental Conditions

The Welland Canal is a man-made channel, cut twenty-seven miles across the Niagara Peninsula between Lakes Erie and Ontario. The canal was built with an economic purpose in mind, that is, to allow ships to transit between the two lakes. To be commercially viable, it was designed just wide and deep enough to handle the largest ships expected to be required in Great Lakes trade during its economic life. Canal banks were constructed to withstand high current forces and wave energies caused by such ships. Similarly, the channel bed was built to withstand high currents and the severe scouring forces of ships' propellers. The canal was also designed to accommodate (structurally and environmentally) anticipated increases in water demand for navigation, power and other uses. In this context, the "environment" for the Welland Canal is a contrived feature which was never intended to stabilize completely. Testimony to this is a long history of continuous change, upgrading and re-routing; in fact, the canal has been completely re-built four times in its one hundred and fifty-year history. Environmental impacts on the canal have gone virtually unrecognized as such, with the minor mitigating modifications being made as part of everyday events on the canal.

4.4.5 Amount of Diversion and Limitations

The present diversion has averaged 7,600 cfs from 1952 to 1976, with a maximum annual average of approximately 8,500 cfs. The diversion was increased for a time in 1973-74 to offset the reduced diversion during the fall and winter period, 1972-1973, because of construction on the Welland Canal. About 700 cfs of this diversion is discharged into the Welland River for water quality purposes and thereby returned to the Niagara River above the falls. The average has increased to 7,800 cfs for the period 1952-79, with a maximum value of 9,300 cfs in 1979. As mentioned above, the maximum annual mean flow will be unlikely to exceed 9,400 to 9,500 cfs.

The International Joint Commission has not exercised control over flows in the canal. The Board has not attempted to interpret the Commission's authority to exercise such control. However, the amounts of water diverted are reported to the two governments by the International Niagara Committee.

4.4.6 Hydrologic Effects of Existing Diversion

The diversion of water through the Welland Canal increases the outflow capacity of Lake Erie. With an average of 7,000 cfs, the level of Lake Erie would be lowered by about 0.32 foot. Because the level of Lake Erie to some degree affects the levels of Lakes Michigan-Huron and Superior, the levels of these lakes have dropped about 0.17 foot and 0.04 foot respectively, due to diversion of water through the Welland Canal. Increasing this average to an annual value of 9,400 cfs will lower Lake Erie by an additional 0.08 foot (a total lowering of 0.40 foot), Lakes Michigan-Huron by 0.05 foot (total 0.22 foot), and Lake Superior by 0.02 foot (total 0.06 foot).

4.5 NEW YORK STATE BARGE CANAL

4.5.1 General

The New York State Barge Canal System, owned and operated by the State of New York, consists of four interconnected canals (see Figure 4-9): the Champlain, Erie, Oswego and Cayuga-Seneca Canals. They were originally constructed in the early 1800s and reconstructed in their present form in 1918 for the purpose of developing the commerce of New York State.

4.5.2 History

The idea of joining the Hudson River to Lake Erie with a man-made waterway was first conceived in 1808. Construction of the Erie Canal began in 1817 and was completed eight years later in 1825. The completed canal contained 83 locks and stretched 363 miles from Buffalo to Albany, New York and an additional 150 miles down the Hudson River to New York City. The original canal's 40-foot width and four-foot depth, with its locks 90 feet in length and 10 feet in width, enabled barges pulled by mules to haul up to 30 tons of cargo along the system at a rate of three to five miles an hour.

During the 1840s and 1850s the canal was enlarged to a depth of seven feet and a width of 70 feet and the locks were expanded. Commerce flourished along the canal and traffic increased to over six million tons

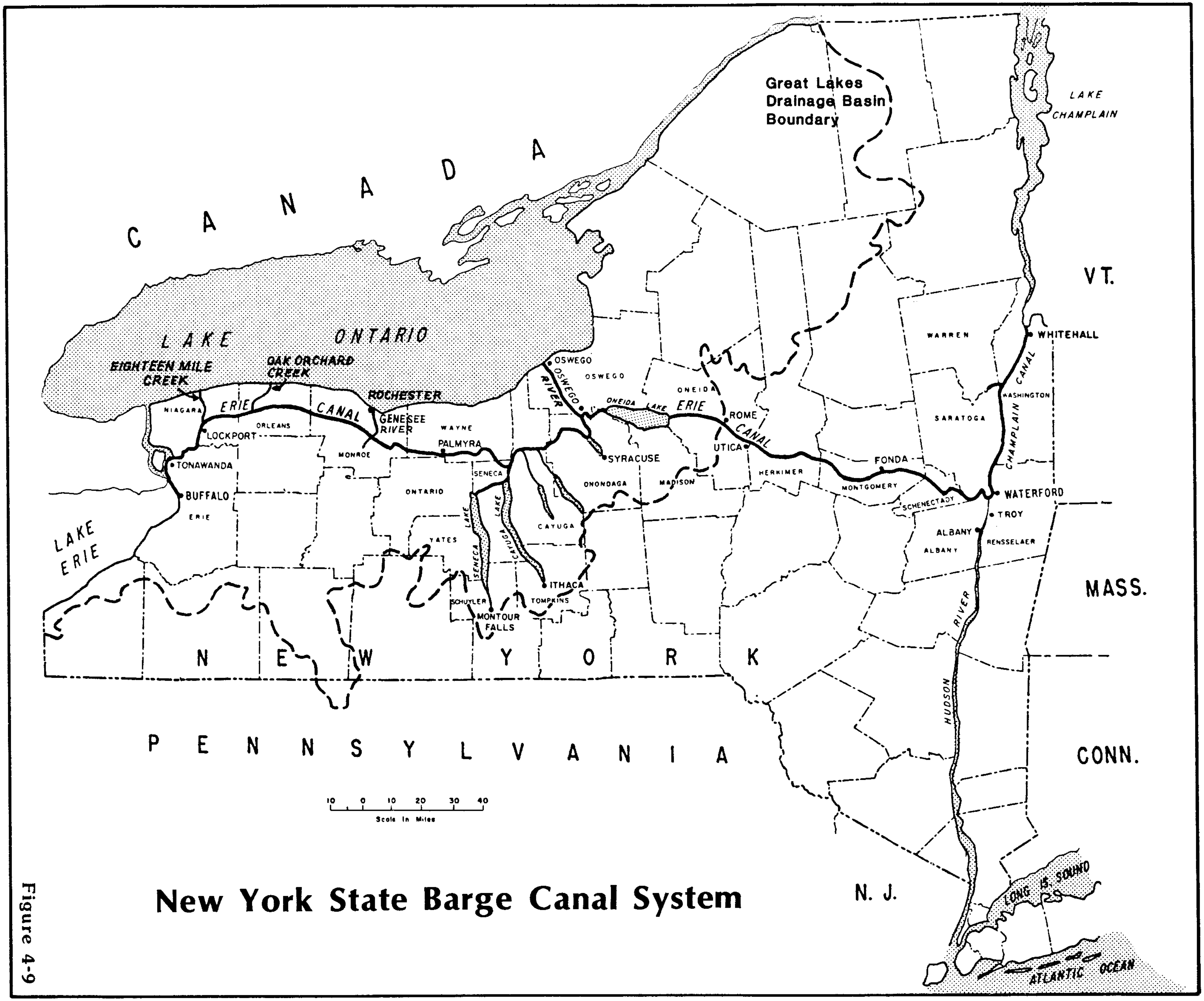


Figure 4-9

New York State Barge Canal System

a year by 1868. By the early 1880s user fees on the canal had generated $42 million more than the $78 million required to build, operate, maintain and enlarge the canal. In 1883, due to competition with the railroads, canal traffic began to drop. In order to prevent further loss of traffic, a state-wide referendum allowed the tolls on the canal to be discontinued.

Work began on the present New York State Barge Canal System in 1905 and was completed in 1918. Despite the fact that the new barge canal was the most modern inland waterway in the world, and considerably larger than the old Erie Canal, it never carried as much traffic in any year as the original canal did.

4.5.3 Description of the Present System

The Champlain Canal, located in the east central portion of New York State, extends from the Hudson River at Waterford, New York, to Whitehall, at the head of Lake Champlain. The Erie Canal crosses the length of New York State and joins the Hudson River at Waterford with the western part of New York State at Tonawanda and Buffalo on the Niagara River. The Oswego Canal connects the Erie Canal at Three Rivers Point with Lake Ontario at Oswego. The Cayuga-Seneca Canal connects with the Erie Canal at the junction of the Seneca and Clyde Rivers, and extends to Ithaca on Cayuga Lake and to Montour Falls, just south of Watkins Glen, on Seneca Lake.

The entire barge canal system is 512 miles long and consists of 214 miles of artificial land-cut channels and 298 miles of canalized rivers and lakes. The controlling depth of the system is 12 feet, except for the eastern Erie section running from the Hudson River to Three Rivers Point and the Oswego section, which are 14 feet deep. The deepening of these sections was part of the improvement project funded by the 1935 Rivers and Harbors Act. In the eastern Erie section the channel is 200 feet wide in rivers and lakes, 104 feet wide in earth cuts and 120 feet wide in rock cuts. The remaining sections are all 200 feet wide in canalized sections, 75 feet wide in earth cuts and 94 feet wide in rock cuts.

There are 57 locks on the barge canal having a combined lift of 1,018.4 feet. Most of the locks are operated using the original equipment installed over 60 years ago. Several of the locks have been modernized and the old mechanical machinery has been replaced by hydraulic systems. Locks on the canal are 310 feet long and 45 feet wide with usable space for a barge 300 feet long and 43.5 feet wide. In comparison to modern waterways like the Mississippi and Ohio systems the locks on the barge canal are small. Table 4-3 summarizes much of the above.

The water diverted from the Niagara River into the canal enters Lake Ontario by four routes in New York State: at Lockport, into Eighteen Mile Creek; at Medina, into Oak Orchard Creek; at Rochester, into the Genesee River; and additionally, via the Oswego river. Water is diverted at various locations along the canal for irrigation purposes (an indeterminant amount) and power production at Lockport, New York. In addition, the water returned to Lake Ontario is used for power production

Table 4-3
PHYSICAL DATA ON CANALS IN THE NEW YORK STATE BARGE CANAL SYSTEM

				WATERWAY DIMENSIONS					
				Canalized river sections and lakes			Land cuts and rock sections		
Waterway	Lift (feet)	Length (miles)	Number of locks(a)	Length (miles)	Width (feet)	Depth (feet)(b)	Length (miles)	Width (feet)	Depth (feet)(b)
Champlain Canal (Waterford to Whitehall)	168.3	60	11	36	200	12	24	75 in earth, 94 in rock	12
Erie Canal (Waterford to Tonawanda) (c)	660.5	338.2	34(d)	161	200	(f)	177	(e)	(f)
Oswego Canal (Great Lakes to Hudson River Waterway-Three Rivers Point to Oswego on Lake Ontario) (c)	118.6	23.8	7	23	200	14	1	104 in earth, 120 in rock	14
Cayuga-Seneca Canal (Mays Point to Ithaca and Montour Falls)	71.0	90	4	78	300-110	12	12	75 in earth, 94 in rock	12
Total	1,018.4	512	56(d)	298			214		

(a) Lock chambers are 310 feet long, 45 feet wide, with 12 feet over lock sills except as noted in comment (c) below.
(b) Depth in feet at normal pool level.
(c) The east section of the Erie Canal (Waterford to Three Rivers Point) and the Oswego Canal (Three Rivers Point to Oswego on Lake Ontario) constitute the existing federal project for the Great Lakes to Hudson River Waterway.
(d) In addition, there is one lock, the Utica Harbor Lock, maintained as part of the canal system.
(e) 104 feet in earth and 120 feet in rock for the east section, 75 feet in earth and 94 feet in rock for the west section (Three Rivers Point to Tonawanda).
(f) 14 feet for the east section (part of the existing federal project), 12 feet for the west section.

at two plants on Oak Orchard Creek, one plant on the Genesee River and six plants on the Oswego River.

4.5.4 Environmental Conditions

(a) General. Throughout the region traversed by the New York State Barge Canal System, both waters and wildlife have been extensively modified by man's activities. In some parts of the system the variety of fish fauna has increased due to the stocking of non-native species and the translocation of other species via migration through interconnecting canal waterways. In other parts, however, reductions in fish fauna have occurred. Anadromous fish spawning runs have been blocked by dams and wetland spawning areas have been eradicated by drainage and dredging programs. Many natural, food-rich, riffle streams have been degraded by channelization and water quality has deteriorated as a result of domestic, agricultural, industrial and navigational pollution. Lakes have been created, and/or modified, by flood control projects, and stream flows and temperature regimes have been altered by engineering works. All of these factors have combined to exert a significant impact on aquatic resources. In most instances, however, the extent of this impact has not been well documented.

(b) Fish. Fishery habitat within the New York State Barge Canal System and attendant waters varies from high to low quality. Habitat types, which range from warm to very cold and slow moving to swift, include small brooks, large rivers and lakes. For the most part, the drainage areas of the Mohawk River, Oneida River, Oswego River, Seneca River, Clyde River, Niagara River, Lake Oneida, Cross Lake and the land-cut sections of the canal support warmwater fishes. Lake Erie, Lake Ontario, Seneca Lake and Cayuga Lake support both warm and coldwater fish. Most tributaries of these main bodies of water are partially or totally coldwater species habitat. In general, the highest quality fishery habitat is found in unchannelized and undammed portions of basin streams. These are followed in descending order of quality by large channelized streams and lakes, fully channelized streams, and single purpose industrial reservoirs. The lowest quality fishery habitat is represented by land-cut canal sections.

Fishery resource inventories of the various drainage areas bounded by the New York State Barge Canal System have been sporadic both in distribution and magnitude over the past 50 years. The biological surveys conducted around the 1930s by the New York State Conservation Department remain the only information available for many sections of the barge canal. Pertinent surveys are those covering the Erie-Niagara, Lake Ontario, Oswego River and Hudson-Mohawk watersheds.

In all, 133 fish species have been documented for the entire barge canal system. The principal game fish known to be within the drainage areas of the system are smallmouth bass, largemouth bass, chain pickerel, northern pike, muskellunge, American eel, rainbow smelt, sauger, walleye, brown trout, brook trout, rainbow trout, lake trout and Atlantic salmon. Popular panfish include pumpkinseed, green sunfish, bluegill, rock bass, black crappie, white crappie, redbreast sunfish, white bass, white perch and yellow perch. Dominant ictalurids include the brown bullhead and channel catfish. Large forage species include carp, goldfish, white sucker, shorthead redhorse, quillback bowfin, longnose gar and freshwater drum. Juvenile blueback herring have been found in the eastern section of the Erie Canal and the sea lamprey is distributed throughout the entire New York State Barge Canal System.

Sizeable salmonid stocking programs have been undertaken by the New York State Department of Environmental Conservation in a number of drainage areas and waters adjacent to the barge canal. Lake trout, brook trout, brown trout and rainbow trout have been stocked in tributaries of Oneida Lake, Seneca Lake, Cayuga Lake and the Mohawk River. Chinook and coho salmon have been stocked in both Lake Erie and Lake Ontario and catches have been recorded in the Niagara River and the mouth of Tonawanda Creek, waters attendant to the western portion of the barge canal.

Aside from these stocking programs and the inventories previously mentioned, little other fisheries work has been conducted on the main canal by the New York State Department of Environmental Conservation, U.S. Fish and Wildlife Service or any other educational or environmental agency. Consequently, adequate comprehensive, qualitative and quantitative data describing the current fishery resources of the New York State Barge Canal System are lacking.

(c) Water Quality. Discharge of pollutants into the canal system has been, and continues to be, a serious threat to aquatic life. Domestic and industrial effluents from the Cities of Buffalo, Tonawanda, Fulton, Oswego, Rochester, Rome, Utica and Schenectady, have created low dissolved oxygen levels in canal waterways (State of New York Conservation Department 1928, 1929, 1935, 1940). Although some of the more severe pollution problems have been improved in recent years, Haines and Ellis (1977) found continued evidence of domestic pollution in the form of high coliform bacteria counts in the western portion of the Erie Canal. The New York State Department of Health has monitored water quality and conducted benthic inventories along the barge canal from Tonawanda to Albany. It reports the presence of heavy loads of organic pollution in those portions of the canal between Tonawanda and Hulberton, downstream of Rochester to Palmyra, downstream of Rome to east of Utica, and in the Scotia-Schenectady area. The effects of both organic and toxic pollutants were detected in these reaches; the oligochaete worm, which is tolerant of low dissolved oxygen levels, is the major benthic organism present. A heavy metals problem was evident in the Rome-Utica area. These pollution problems are detrimental to a healthy fishery because they lead to the survival of less desirable fish over game fish and more often than not lead to fish kills.

The residues of organochlorine compounds used in agricultural pesticides have also been found in bottom sediments throughout the canal system. Collectively, these toxic chemicals represent an extreme danger to aquatic life and man. They do not break down quickly in the environment and therefore readily become concentrated in the aquatic food chain. Organochlorine compounds are known to inhibit reproduction of fish, birds and mammals.

Thermal pollution in the New York State Barge Canal System is also a problem and occurs principally in tributary streams on which dams have been constructed. The large surface area of the impounded water is easily warmed during the summer months. When released downstream, the warm water renders former salmonid habitat incapable of supporting trout populations.

Practices controlling the canal's water level are also detrimental to fishery resources. Many sections of the barge canal are drained annually during the winter months, thereby abusing substantial acreages of aquatic and benthic habitats. Benthic production is not only suppressed by intrusions of municipal and industrial organic and toxic wastes, but more importantly, also by physical disruptions of the tributary streams through operation and maintenance of the barge canal. Probably the most important factor contributing to this condition is the loss of micro-habitat caused by replacing the normal succession of riffles and pools with a series of navigation pools of generally uniform depth and current velocity.

(d) Wildlife/Wetlands. By far the most important and valuable wildlife habitat associated with the project area are wetland acreages. Valuable wildlife species associated with the canal include furbearers, small game, big game, waterfowl and songbirds. Muskrat, beaver, mink and weasel populations are directly dependent on the wetlands adjacent to the canal. Muskrat populations are large and support a significant trapping effort. Other mammals supported by the wetlands are the racoon, gray fox, red fox, coyote, cottontail rabbit and white-tailed deer.

Resident and migratory waterfowl are abundant. Adjacent canal wetlands provide these birds with necessary refuge, food and breeding grounds. Mallards, black ducks, blue-winged teal, green-winged teal and wood ducks are the dominant resident species. Waterfowl that frequent the area as migrants include the Canada goose, pintail, shoveler, gadwall, American widgeon, common goldeneye, redhead, canvasback, greater and lesser scaup, buffelhead, white-winged scoter and hooded merganser.

In addition to waterfowl many other species of birds are found in abundance within the wetland habitat. Chamberlain (1974) and Page (1975, 1978) have documented over 140 species of birds at Utica Marsh and other wetlands within the Mohawk River floodplain. Data on the abundance and distribution of birdlife are lacking for other regions of the barge canal system. However, on the adjacent Montezuma National Wildlife Refuge alone, over 280 species of birds can be observed throughout the year. Herons, terns, shorebirds and songbirds are common in the refuge while waterfowl number as high as 140,000 geese in April and 150,000 ducks in October. Large numbers of birds that feed, nest or rest on the refuge also utilize wetland areas adjacent to the barge canal beyond the refuge boundaries.

Endangered Species

Federally-designated endangered wildlife species associated with the barge canal include the bald eagle and the American peregrine falcon. New York State-designated endangered species are the osprey and the bog turtle. The bald eagle, osprey and peregrine falcon are migratory and no nesting sites are known, except for a bald eagle reintroduction program underway at the Montezuma National Wildlife Refuge. Both the bald eagle and osprey can be considered wetland dependent as their principal food is fish. Habitat suitable for the bog turtle exists in the drainage areas of the Upper Hudson, Lake Champlain, Mohawk River and Oneida River. Data on its current abundance and distribution are lacking. Other endangered or threatened flora and fauna in the barge canal system have not been identified at the present time.

Wetlands

It is estimated that there are 27,500 acres of wetland contiguous to the main barge canal system from Tonawanda to Troy, excluding the Montezuma National Wildlife Refuge and the state-owned Howland Island Game Refuge. There are an additional 900 acres of wetland along the Oswego River between Three Rivers Point and Lake Ontario. Many other large and small privately owned wetlands, formed by littoral lake areas, oxbows, bypassed river sections or canal wide waters, plus permanent and seasonally flooded marshes and swamp are present throughout the barge canal system. Exact acreages are unknown and remain to be identified.

Several unique and valuable wetland areas necessary for the perpetuation of water-dependent wildlife have been preserved in spite of continued maintenance dredging and spoil disposal within the barge canal. Both the federal and state governments have purchased wetlands for protective and management purposes. The two largest wetland refuges within the canal drainage system are the 6,000-acre Montezuma National Wildlife Refuge and the 3,600-acre Howland Island Wildlife Refuge. Table 4-4 summarizes estimated wetland and open water acreages associated with the barge canal system.

Recreational Resources

The New York State Department of Environmental Conservation reports that waterfowl and small game hunting is allowed along most portions of the canal's length except on lands adjacent to locks and towns. Utilization for hunting varies from light to heavy, depending on access and habitat quality. Muskrats support an extensive trapping effort throughout the canal system, but the canal's contribution to the overall state trapping effort is unknown. Use of the canal system for fishing also varies from light to heavy, depending on water quality and access. Fishing within the Mohawk and Oneida drainage areas is light due to public suspicion that the fish are contaminated by pollution. However, with a decrease in pollution sources and increased public awareness of the fishery potential, fishing is expected to increase in the future. Recent aerial census data provided by the state conservation agency show a marked increase in angling along the Mohawk River between St. Johnsville and Cohoes from 1973 to 1977. The average number of anglers per flight mile quadrupled in a four year period. Although utilization of the Oneida River for fishing can be described as heavy, actual data on angler use are unavailable.

Additional recreational activities have been documented by Haines and Ellis (1977), who conducted a limited recreation use survey (124 observations) along the barge canal from Lockport to Clyde, New York, during May, June and August, 1976. Six different recreational activities were observed. Fishing was the most important activity and accounted for

Table 4-4

WETLANDS AND WATERS OF THE NEW YORK STATE BARGE CANAL SYSTEM

Waterway or Other	Acres of Wetlands	Acres of Open Water
Erie Canal (Tonawanda to Troy)	27,545	19,326
Oswego Canal (Three Rivers Point to Oswego)	888	2,167
Seneca-Cayuga Canal (Seneca Park to Clyde River)	655	701
Cross Lake	--	1,920
Oneida Lake	--	50,000
Onondaga Lake	--	3,010
Montezuma National Wildlife Refuge	6,000	--
Howland Island Wildlife Refuge	3,600	--
Vanderbilt Marsh	1,900	--
Galen Marsh	600	--
Oneida and Herkimer Counties (Private)	11,500(1)	--
Totals	52,688	77,124

(1) It is not known what proportion of this figure is included in the total for the Erie Canal (Tonawanda to Troy).

41 percent of all users observed. Relaxing, pleasure boating, hiking, bicycling and swimming, in descending order of importance, were the other activities observed. More intensive studies of this type are needed if the recreational resources of the project area are to be adequately assessed.

4.5.5 Amount of Diversion and Limitations

The amount of water diverted through the canal from the Niagara River varies seasonally and averages about 700 cfs with a maximum flow during the navigation season (April to November) of 1,100 cfs, which is the limiting flow. A control gate near Pendleton, New York, permits the canal to be de-watered during the non-navigation months.

The International Joint Commission has not exercised control over flows in the canal. The Board has not attempted to interpret the Commission's authority to exercise such control. However, the amounts of water diverted are reported to the two governments by the International Niagara Committee.

4.5.6 Hydrologic Effects of Existing Diversion

The New York State Barge Canal has a very limited capacity and draws its water from the Niagara River at Tonawanda, New York. Tonawanda is located downstream of the natural hydraulic control section of the Niagara River. Hence, any water withdrawn below the hydraulic control section has no effect on Lake Erie or the lakes upstream. However, the diversion results in a reduction of flow of the Niagara River below Tonawanda.

4.6 Other Minor Diversions

During the course of the study, the existence of a number of small diversions came to the Board's attention. Two minor diversions, the Detroit domestic water system and the Simcoe Diversion, are briefly described below as examples of small, and often undocumented, diversion projects in the Great Lakes basin.

Since 1975, the Detroit, Michigan domestic water system has withdrawn approximately 145 cfs from Lake Huron, the bulk of which is returned to the system. However, this diversion has no effect on Lake Erie levels and non-measurable impacts on Lake Huron levels. The Detroit domestic diversion was investigated further under the consumptive uses portion of the study.

The Simcoe Diversion is a municipal sewage disposal project which is still in the development stage. Municipal sewage flow from several municipalities in the Lake Simcoe (Georgian Bay) drainage basin will be pumped to the Lake Ontario drainage basin via the York-Durham sewer system for treatment at Pickering, Ontario. The flow is estimated to reach 25 cfs by the year 2000 and constitutes a diversion from Lake Huron to Lake Ontario.

Section 5

SELECTION OF LEVEL AND FLOW REGIME FOR COMPARISON PURPOSES

5.1 General

Throughout the last 100 years man has intervened in the natural regime of the Great Lakes. This intervention has resulted in changes in the amount of diversions into, out of or within the Great Lakes, improvement and changes to the configuration of the connecting channels and the construction of control works at the outlets of Lakes Superior and Ontario. The recorded data reflect these changing conditions over time and, therefore, do not provide for a uniform comparison base. In order to provide this uniform base (basis-of-comparison) a set of levels and outflows has been computed, employing the recorded water supplies, assuming the physical and other conditions had been constant instead of varying, during the study period.

The following paragraphs provide a summary of the recorded and derived data used in this study to establish the "basis-of-comparison" (Subsection 5.6). Derived data for this report are contained in the Appendix A "Coordinated Basic Data" and are stored in the United States at the offices of the Detroit District, Corps of Engineers and in Canada at the offices of the Inland Waters Directorate, Federal Department of the Environment, Ottawa, Ontario.

5.2 Selected Study Period

Although observations of the water levels of the Great Lakes have been taken almost continuously since 1860, only a few discharge measurements of the outflows from the lakes were made prior to the turn of the century. In order to use as uniformly consistent and reliable observations as possible for each of the lakes and their outlet rivers, and also to have a reasonably long record for developing and evaluating diversion management scenarios, the period from January 1900 to December 1976 was selected for this study. This 77-year period is referred to as the "study period" throughout this report. It contains basin-wide droughts, such as those of the mid-1930s and mid-1960s, as well as several high supply periods, such as those in 1928-1929, 1951-1952 and 1971-1973. For this reason, it was considered that hydrologic conditions in the Great Lakes basin over the 77 years are satisfactorily representative of the hydrology of the Great Lakes and suitable as a base for evaluating the effects of diversions and consumptive uses.

5.3 Recorded Data

The recorded data, such as water levels, river flows and diversions, were taken from records on file in the United States at the National

Oceanic and Atmospheric Administration, Department of Commerce, and at the Department of the Army, Detroit District, Corps of Engineers; and in Canada at the Inland Waters Directorate, Department of the Environment, and the Marine Environmental Data Service of the Department of Fisheries and Oceans. The values developed by the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data and agreed to by user federal agencies of both countries were employed where possible. Where required coordinated data did not exist, the missing information was developed during the study.

5.4 Assumptions

To determine the required water supply data (Subsection 5.5.1) and develop the basis-of-comparison the following assumptions were made:

a. that no adjustments would be made to the recorded data to reflect changes in the characteristics of the Great Lakes basin over the study period; such as, tributary stream regulation, increased urbanization, deforestation, consumptive uses, etc.;

b. that due to the large area of each of the Great Lakes in comparison to changes in the area as a result of changes in level, a single storage conversion constant can be used for each lake, valid over its entire range of levels. These constants relate a change in level, measured in feet, to the volume of water represented by it, measured in cfs-months. They are as follows:

Lake Superior	= 0.00296 foot per thousand cubic feet per second for one month (tcfs-mo.) or 337,800 cubic feet per second for one month per foot, (cfs-mo./ft.)
Lakes Michigan-Huron	= 0.00208 ft./tcfs-mo. or 480,800 cfs-mo./ft.
Lake Erie	= 0.00951 ft./tcfs-mo. or 105,200 cfs-mo./ft.
Lake Ontario	= 0.0125 ft./tcfs-mo. or 80,000 cfs-mo./ft.;

c. that all months have the same number of days (30.4 days).

5.5 Derived Data

Derived data include the lake basin supplies and seasonal flow retardations in the connecting channels. Due to their larger surface areas, the levels of Lakes Superior and Michigan-Huron are less sensitive to changes in water supply than the levels of Lakes Erie and Ontario. For example, the Lake Ontario response is six times larger than Lakes Michigan-Huron. For this reason, the basic data used in this study were developed and coordinated in monthly periods for Lakes Superior and Michigan-Huron and in quarter-monthly periods for Lakes Erie and Ontario. Since Lake St. Clair reflects conditions mainly on Lakes Michigan-Huron, monthly periods were employed on that lake. Data derived for this study are described in the following subsections.

5.5.1 Net Basin Supplies

Net basin supply is a term used to describe the water which a lake receives from precipitation on its surface and runoff from its own land drainage basin less the net effect of evaporation from and condensation on the lake surface. Although presently available techniques do not permit the accurate determination of these factors separately, net basin supplies can be computed quite accurately by employing reliable lake level, flow and diversion records for the required monthly and quarter-monthly periods. The relationship used is as follows:

$$NBS = S + O - I$$

where:

NBS = Net basin supply.
S = Change in storage from beginning to end of period.
O = Average outflow from lake through outlet river, plus flow diversions out of the lake.
I = Average monthly inflow to lake from upstream plus flow diversions into the lake.

All terms in the above relationship are expressed in consistent units, usually cfs, for the given period.

5.5.2 Seasonal Flow Retardation

The flows in the outlet rivers of the lakes during the winter season are often retarded substantially by ice formation and ice jamming. These conditions are not predictable for any specific winter, either as to their severity or the exact timing of their occurrence. The natural retardation of flow under ice conditions causes the levels of unregulated lakes to be higher at the time of the spring break-up than they would be if there were no ice, and thus increases the amount of water stored in the lake.

The water level of Lake Superior and the outflow through the St. Marys River are regulated by the International Lake Superior Board of Control under authority of the IJC. Physical control is achieved by a dam and other structures at the head of the St. Marys Rapids at Sault Ste. Marie, Michigan and Ontario. Under present regulation conditions, the winter retardation effect on the regulated discharges is virtually zero. Since the basis-of-comparison condition for Lake Superior is considered to be the present regulation plan, it was not necessary to consider winter retardation in the St. Marys River.

Lakes Michigan-Huron do not freeze over completely during the winter, primarily due to the influence of wind and of heat stored in the lake. The ice which forms in the exposed central parts of the lake is continually broken up and moved about by the action of the wind. Some of the ice from

Lake Huron finds its way into the St. Clair River. As a result of these heavy runs of ice, jams occur which substantially reduce the normal flow and in turn affect both upstream and downstream levels. The average flow reduction, January through March, is 28,000 cfs. However, the supply of ice delivered to the river and the consequent degree of jamming is highly variable and this is an important factor in the natural winter regime. Any derived basis-of-comparison, therefore, must give consideration to the month by month magnitude of this flow retardation. Winter retardation in the St. Clair River was computed for each month by subtracting the recorded St. Clair River flow (determined by the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data) from the corresponding open water flow computed from the stage-discharge relationship for the gauges at Harbor Beach and St. Clair Shores, Michigan.

Lake St. Clair normally freezes over in early winter and shields the Detroit River from heavy ice runs. The Detroit River itself frequently freezes over in its lower reaches. However, due to the size of Lake St. Clair, even a small retardation (January through March average 8,000 cfs) influences its levels regime. Therefore, each month's winter retardation in the Detroit River was determined to be the difference between the recorded flow and the flow computed from the open water stage-discharge relationship for the gauges at St. Clair Shores, Michigan and Cleveland, Ohio.

Historically the principal ice problem in Lake Erie, as in the case of Lake Huron, results from the break-up of lake ice-fields and the prevailing winds then pushing the ice into the Niagara River. This causes ice jams and also power losses in the hydro-electric plants. Over recent years this problem at the outlet of Lake Erie has been moderated. In each winter since 1964-1965 an ice boom has been installed near the head of the Niagara River. Its purposes are to assist in forming a stable ice cover and to reduce the severity of ice runs in the river under strong southwesterly wind conditions. Hence the average winter flow retardation since 1964 had to be assumed for computation of the basis-of-comparison (Subsection 5.6).

Weeds in the summer also affect the flow in the Niagara River. In previous studies conducted by the Coordinating Committee on Great Lakes Basic Hydraulic and Hydrologic Data, it was determined that this effect was much the same from one summer to another. Therefore the average weed retardation as computed by the Coordinating Committee, was employed. In the other connecting channels, some weed retardation may occur, but the data available are insufficient to confirm these results.

Lake Ontario has been regulated since 1960 and the basis-of-comparison assumes this condition for the entire study period. Therefore, no winter retardation was required for the calculation of effects on the upper St. Lawrence River. Reduction in the winter flow at the outlet of Lake St. Louis was calculated directly as the difference between the discharges derived from its approximate open-water stage discharge curve and the recorded discharges.

5.6 Basis-of-Comparison

The recorded Great Lakes levels and outflows data incorporate the effects of man-made changes in the system which have occurred over the study period 1900-1976. The principal changes consist of variations in the flow of diversions into, out of or within the Great Lakes basin; alterations in the configurations of the connecting channels, such as by dredging for navigation purposes; construction of control works at the outlets of Lake Superior and Lake Ontario; and introduction of, and subsequent modification to, regulation plans for those two lakes.

In order to permit hydrologic comparison of various diversion management scenarios on a uniform basis, an assumed set of constant conditions within the Great Lakes system was adopted and the recorded monthly mean levels and outflows for each lake adjusted accordingly. This was done by routing through the system the historical net basin supplies, assuming a regime defined by this set of fixed conditions. The effects of changes in channels, diversions and lake regulation were thus removed from the data. No adjustments were made in the water supplies for the effects of regulation of tributaries, variations in winter ice retardation or increasing rates of consumptive use.

The conditions selected for the basis-of-comparison are as follows:

(1) A constant diversion of 5,000 cfs into Lake Superior by way of the Long Lac and Ogoki Diversions. These diversions were authorized through an exchange of notes, dated October 14 and 31, and November 7, 1940, between the governments of the United States and Canada.

(2) Lake Superior regulated in accordance with Plan 1977, which is the currently authorized plan being used by the International Lake Superior Board of Control for determining releases from Lake Superior.

(3) A constant diversion of 3,200 cfs out of Lake Michigan at Chicago. This is the maximum allowable diversion at Chicago by decree of the U.S. Supreme Court, dated June 12, 1967, and as amended in 1980.

(4) 1962 outlet conditions for Lake Huron. This represents the current conditions, which have existed since the completion of the 27-foot navigation channel dredging in 1962.

(5) A constant diversion, by way of the Welland Canal, of 7,000 cfs out of Lake Erie and into Lake Ontario. This is consistent with prior and ongoing studies of other Boards and is an approximation of the average annual flow for the period 1950 to 1976.

(6) 1953 outlet conditions for Lake Erie. In its 1953 report on the Preservation and Enhancement of Niagara Falls, the IJC considered it essential that the relationship existing at that time between the Niagara River flow and the Chippewa-Grass Island Pool level be maintained following the commencement of operation of the Chippewa-Grass Island Pool Control

Structure and power diversions as permitted by the 1950 Niagara Treaty. On December 29, 1972, the IJC issued a directive in which it was stated that the pool was to be maintained at its long-term mean elevation of 561.0 feet (IGLD 1955), as recorded at the Material Dock Gauge, to alleviate high or low water levels in the pool. This directive was implemented on March 1, 1973.

(7) Lake Ontario regulated in accordance with Plan 1958-D, which is the currently authorized plan being used by the International St. Lawrence River Board of Control for determining releases from Lake Ontario. It should be noted that on a number of occasions since 1960, the International St. Lawrence River Board of Control has deviated from the approved plan of regulation. The condition represented for Lake Ontario does not contain the effects of these discretionary deviations.

Section 6

CONSUMPTIVE WATER USE

6.1 Introduction

Water supplies from the extensive hydrologic system of the Great Lakes sustain the regional population and support diverse economic and recreational activities within the basin. Although the system is large, the aggregated demands of these numerous users may have an effect on its hydrologic balance. Reductions in inflow and storage from water consumption can result in measurable changes in mean levels of the lakes.

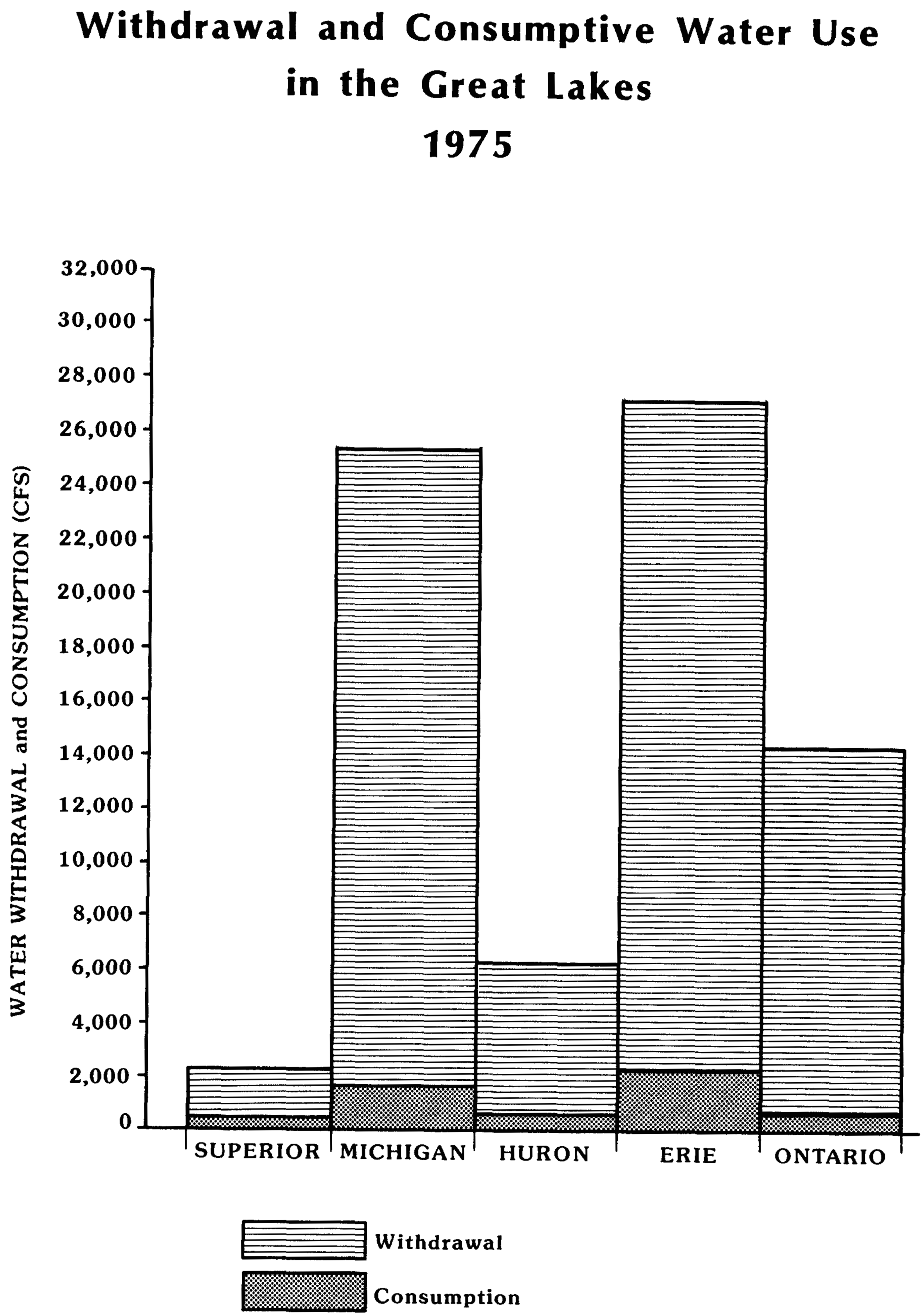
Most of the water withdrawn from the system for human use is eventually returned to the system by direct discharge into lakes and streams or by infiltration into the groundwater table. However, a portion of this water is not returned to its source; it is categorized under the term consumptive use. This includes water which is assimilated by animals, humans and plants; incorporated into products during industrial processes or lost from the system through evaporation or leakage during use. Estimation of the quantities of water withdrawn from the system and consumed in meeting present and future water needs is a necessary prerequisite to determining impacts on lake levels now and in the future.

In a sense, water consumption cannot be totally quantified when applied to a large basin. For example, evaporation of water during use may add some quantity to the natural background precipitation and thus some portion of the consumed water could reappear within the basin. However, quantifying this small amount relative to total precipitation is presently beyond the state-of-the-art in meteorology. Thus, the principle has been adopted that water consumed at any point in the basin is lost to the system.

Although consumptive uses are the subject of this investigation, they have to be viewed in terms of water withdrawals with which they are intimately related and form an integral part. Withdrawal quantities generally are metered and provide a basis from which to derive consumptive use estimates. Water withdrawals in 1975 were extremely large (75,600 cfs) in comparison to consumptive water use (4,900 cfs) (Table 6-3, page 6-51). Consumptive use as a percentage of withdrawals from each lake ranged from 4.8 to 10.4 percent and averaged seven percent in 1975. Lakes Michigan and Erie contributed by far the most withdrawal water and had the highest consumption. (Figure 6-1)

Sectors of water use that are considered in this study are:

(1) Municipal


Withdrawal and Consumptive Water Use
in the Great Lakes
1975
32,000
30,000
28,000
26,000
24,000
22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
WATER WITHDRAWAL and CONSUMPTION (CFS)
SUPERIOR
MICHIGAN
HURON
ERIE
ONTARIO
Withdrawal
Consumption
Figure 6-1

(2) Rural-domestic

(3) Manufacturing

(4) Mining

(5) Rural-stock

(6) Irrigation

(7) Power Generation

Projections of withdrawals and consumptive use of water from the Great Lakes and other surface and groundwater sources within the drainage basin have been prepared for each water use sector in five year increments to the year 2035 with 1975 as the base year. These projections, which have been presented in Tables 6-1, 6-2 and 6-3 (pages 6-47, 6-49 and 6-51 respectively), are based on the data which were available at the time of report preparation and on existing and reasonably foreseeable economic, demographic and social trends. The individual sector discussions that follow display portions of these tables. Minor discrepancies are due to rounding of the numbers.

Similar to most forecasts, water use forecasting has inherent uncertainty; the basis for assumptions upon which projections are based will change in time. Three principal types of uncertainties are involved: economic uncertainty, technological uncertainty and the uncertainties in water management policies. To account for these uncertainties, a range of consumptive water use projections was developed based on a number of alternative assumptions and also on projections derived from independent sources. These then provide a basis for forecasting a range of consumptive water use impacts on Great Lakes water levels.

The forecast considered to be the most reasonably foreseeable projection based on current knowledge and trends will be referred to as the most likely projection (MLP) in this study. The term "most likely projection" is not meant to imply a high degree of probability. Rather this projection is the one judged at this time to have the highest probability of occurring relative to the other projections considered.

A detailed explanation of the methodologies and the extensive set of references used to obtain the MLP and other projections appear in Annex F.

Water use calculations are broken down and totaled by sector and by lake basin in terms of nation and "lake" (referring to all withdrawals and consumption directly from the Great Lakes) or "non-Lake" (referring to all other withdrawals and consumption from within the basin.) The "lake/non-lake" breakdown appears in the supporting Data Set (Annex F).

6.1.1 Constraint Factors

The Board adopted the following four constraints:

(1) The basic data collection and analysis should be done during a one-year period.

Primary research was limited to that which was practical within the given time and budget constraints.

(2) Available data and forecasts should be used as much as possible.

This constraint proved easier to follow for the United States, since extensive forecasting work had already been done. In Canada, the work had a much more fundamental beginning.

(3) The projection methodologies used in both countries should be reasonably consistent to enable subsequent integration of results.

This meant that the Canadian work had to conform as much as possible to already-completed work in the United States. This does not imply, however, consistency in spatial water use distributions and water use parameters which are expected to vary between areas and which reflect separate management policies of the two countries.

(4) No attempt should be made to assess trade-offs that would be necessary to define the socially optimal level of water use into the future.

Reliable water demand forecasts relate directly to accurate economic projections. Since the latter are difficult to make, the consequent precision of water demand forecasting has a significant degree of uncertainty. The collection and analysis of water use data for Canada on a systematic basis has only recently begun, and the requisite statistical series for trend analysis do not yet exist. Simulation modelling with varying input parameters is a common approach to the problem of uncertainty. By analyzing the response of water demands to changes in the underlying parameters, a range of future water uses can be developed. In general, forecasts become progressively more tentative through the course of time.

Water demand forcasts have traditionally been conducted at two levels, the macro or overall regional level and the micro or local level. The present research is a macro level study, aimed at projecting water demands in the Great Lakes basin and its component sub-basins, as opposed to preparing forecasts for individual municipalities. Techniques such as input-output analysis, coefficient analysis, and broad sectoral growth rate analysis have therefore been used. In contrast, studies of the structure of local water demands which use multiple regression techniques to probe the variables "explaining" the levels of particular uses, have not been used. The implication of this point is that the water demand forecasts presented here cannot be disaggregated.

6.1.2 General Assumptions

The following general assumptions have been applied to the MLP in this consumptive use analysis. Although assumptions were carefully reviewed, they are tenuous and, as in any forecast, can change with time.

(1) Water used to fill supply systems for the first time is considered to be a negligible loss.

(2) The annual growth rate in population in the U.S. portion of the basin is 0.9 percent and will decrease to 0.3 percent by 2035. The annual growth rate in Canada will be 1.4 percent to 2035.

(3) Historical trends of migration from rural areas will continue. The significance of this assumption is in the increased per capita water consumption that is implied.

(4) There will be no new economic classifications. The five major industrial categories enumerated in Annex F will accommodate any new developments.

(5) There will be changes in the mix of economic activities (Annex F, Section 4).

(6) Existing uses of energy will persist.

(7) U.S. requirements mandated by the Clean Water Act, 1977 (P.L.95-217) will be met by the year 2000 while existing practices in Canada will continue.

(8) Water quality requirements and the increased value of water will alter the use of water.

(9) The GNP will increase annually at 3.2 percent in the U.S. portion of the basin and 3.5 to 4.0 percent in Ontario.

(10) The economy will operate at full potential, as defined in standard economic forecasts.

(11) Potential environmental damage is not a constraint in economic projections.

(12) Current trends in per capita consumption and in export of agricultural products will continue.

(13) No catastrophic economic emergencies, such as wars, will occur.

6.2 Municipal Water Use

All of the centralized water distribution systems throughout the Great Lakes basin encompassing residential, commercial, institutional and public uses are included within the municipal water use sector. Also included in the analysis are system losses. Manufacturing withdrawals from municipal systems are not included in this sector. They are considered separately in Section 6.4 - Manufacturing Water Use.

6.2.1 U.S. Municipal Water Use

Municipal water demands shown below and in Table 6-1 comprise the third largest withdrawal water use within the U.S. section of the Great Lakes basin. Specific municipal water use data, based on the MLP, are as follows:

MLP Projection

	1975	2035	Annual Growth Rate
Withdrawal (cfs)	6,100 (10%)	10,800 (8%)	1.0%
Consumption (cfs)	680 (16%)	1,200 (5%)	0.9%

Note: (--) in this and later tables, the bracketed figures show the specific withdrawal or consumption for 1975 and 2035 as a percent of the total withdrawal or total consumption for those years.

The above table shows that while both withdrawals and consumption are expected to increase in absolute terms from 1975 to 2035, the proportions of both the total withdrawals and total consumption required for municipal use in 2035 are projected to decline from those for 1975 due to relatively large consumptive use increases in the manufacturing and power generation sectors.

Five U.S. municipal water use projections were selected to reflect a range of water usage (Figure 6-2).

The U.S. MLP incorporates the assumptions used in the 1975 National Water Assessment (NAS)[1/] which includes the OBERS[2/] Series E population forecasts but applies three modifications. These include a modification of the NAS assumption that expected future increases in municipal water use will be equalled by increased conservation efforts, the addition of water usage attributed to net leakage from municipal systems that extract water from the Great Lakes, and interbasin water transfer.

[1/] The 1975 National Water Assessment is commonly referred to as the National Assessment Study or NAS.

[2/] An integrated set of projections developed by the Bureau of Economic Analysis, formerly Office of Business Economics (OBE), U.S. Dept. of Commerce and the Economic Research Service (ERS), U.S. Dept. of Agriculture. Widespread acceptance of the term OBERS has led to its use as a descriptive title of the program.

Alternative Projections of U.S. Municipal Water Consumption Total Great Lakes

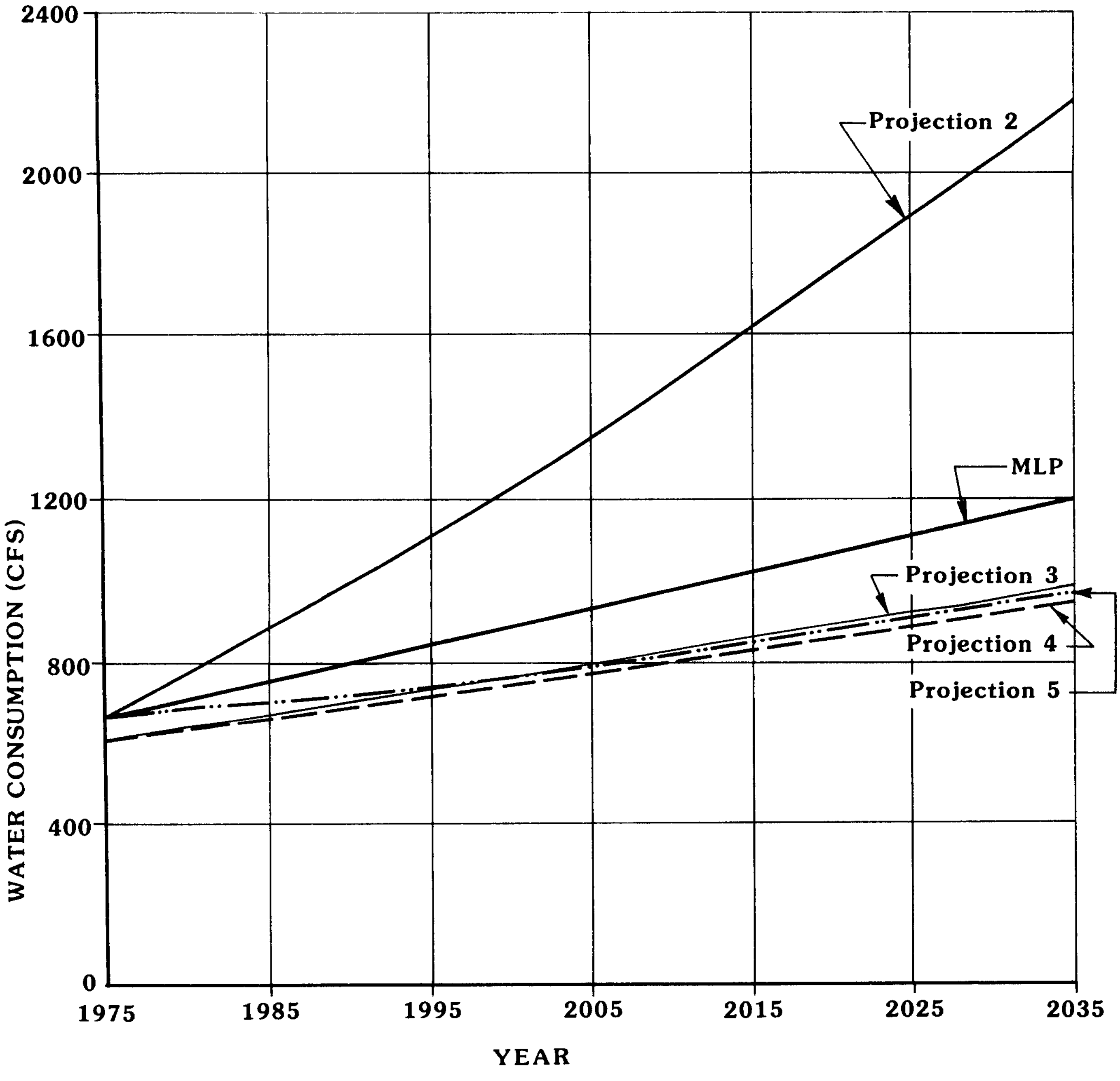


Figure 6-2

The NAS assumption of conservation may be applicable to water use trends in regions of the United States where surface water is less abundant than in the Great Lakes basin. However, current evidence does not suggest that a broad program of water conservation will be adopted by municipalities adjacent to the Great Lakes. Conservation efforts may be undertaken by inland communities supplied by water sources other than the Great Lakes that might have a greater incentive to conserve water to protect their available supplies. Therefore, a distinction in expected water use trends was made between the Great Lakes population served by lake and by non-lake sources.

Leakage is a problem common to urban municipal systems with extensive networks of water pipelines of varying ages and operational conditions. The bulk of the Great Lakes population is serviced by such systems. Standard estimates for net leakage losses from municipal systems range from two gallons per capita per day (gpcd) to five gpcd. The more conservative two gpcd for the lake-served population has been used to represent these expected losses. These leakage losses are assumed to be 100 percent.

The third modification to the municipal NAS figures had an effect on water use totals for Lakes Michigan, Huron and Erie. The NAS did not account for the portion of the Detroit water supply that is withdrawn from Lake Huron and is released to Lake Erie. Also, the NAS forecast considered the water diverted to the Mississippi River basin at Chicago as water consumed from the Lake Michigan basin. This study does not consider that volume in the water consumption estimates because it is accounted for as one of the Great Lakes diversions in this study. The Lake Huron diversion (145 cfs) is too small to be significant in the analyses of diversion impacts.

Projection 2 was developed from the Great Lakes Basin Framework Study.1/ The forecast was adjusted to the 1975 base year, the Lake Michigan Division at Chicago was subtracted and the Lake Huron diversion and central system leakage were added. Projections of municipal water requirements were based on 1972 OBERS Series C population forecasts2/ and projections of per capita use trends for domestic and commercial users. This projection represents the high estimate of municipal water use as population is the most sensitive variable.

1/ Great Lakes Basin Commission (GLBC).

2/ OBERS Series C forecasts are based on population trends of the middle 1960s. They are about 14 percent higher than Series E forecasts by the year 2000.

Projection 3 was extracted directly from NAS. These figures were developed according to the U.S. Geological Survey 1975 estimates of domestic and commercial water use from central systems projected to 2000 on the basis of OBERS Series E population forecasts. Trends were then projected to 2035.

Projection 4 was derived from population projections obtained from state census reports rather than from the national census. The population estimates were generated by agencies within the states during various years from 1975-1978. These population estimates are more complete than those generated in the Clean Water Act, Section 208 water quality management programs. There are no significant differences between the state census, available Section 208 and OBERS-E population estimates. All other assumptions are the same as in projection 3.

Projection 5 is the conservation scenario and the low estimate of municipal water use. Conservation of water supplies has recently been encouraged in some areas of the Great Lake basin, primarily to reduce treatment plant overloading and resultant downstream pollution. Urban areas located inland may also be interested in conservation to avoid the need to develop new supplies. Economic analyses undertaken in such places as Buffalo, New York indicate that conservation can provide financial benefits by eliminating the need for expansion of treatment facilities and groundwater supply systems. One cause of increased interest in efficient use of water was the drought of 1976 and 1977 which affected portions of the Great Lakes region. Droughts similar to this could occur at any time and the threat of such events may encourage future water conservation efforts (Annex F).

All state and regional planning agencies must consider a water conservation alternative in their applications for wastewater treatment construction grants under Section 201 of the Clean Water Act of 1977. Regulations implementing Section 208 of that act require that states and regional planning agencies examine water demands over a 20-year planning period for their water quality management planning. Regulations implementing the Safe Drinking Water Act will significantly increase the cost of supplying water to communities. These costs will encourage states and municipalities to determine the extent to which water conservation programs will be cost effective. Each of the Great Lakes states has given some consideration to water conservation in various water supply planning efforts.

The movement toward water conservation has become sufficiently active that a conservation scenario was thought to be a viable projection of future water use trends. The MLP was used as a base for these figures with the added assumption of a 10 percent reduction in per capita withdrawal and consequent consumptive use to be attained by the year 2000 which reflects the possible results of water conservation programs. The estimate of 10 percent reduction in water withdrawal was selected after reviewing published estimates of water savings gained from the installation of conservation devices in suburban homes.

6.2.2 Canadian Municipal Water Use

Population forecasts were obtained from the province of Ontario and from these, two scenarios, based on a low and a medium fertility assumption, were selected as reflecting potential paths of population growth (Annex F). Because population forecasts were on a county basis, they had to be adjusted to include only that population residing in the Great Lakes basin. They were then aggregated to the individual lake basins. Following this step, the population forecasts for each basin were disaggregated to their municipal and rural components. The analysis of municipal water withdrawal coefficients then proceeded and a range of coefficient values for major municipal water uses was selected. Estimates of future municipal water withdrawal were then made for each lake basin by multiplying the projected population levels by the water withdrawal coefficients. Since there are two population scenarios and four coefficient levels, a total of eight complete water use forecasts were made. Three of these sets, the highest forecast, the lowest forecast and the MLP are discussed here (Figure 6-3).

Coefficients for the major components of municipal water use, residential and commercial, arranged in county groupings show considerable variation. The mean residential water use coefficients vary from a low of 53.7 gpcd to a high of 100.4 gpcd. The mean commercial water use coefficients vary between 10.0 and 28.0 gpcd, with an areal variation similar to that outlined for the residential coefficients. Sources of variation in the two sets of coefficients rest mainly with estimation problems and different classification methods. System losses were taken at 10 percent of the residential plus commercial water use coefficients (6-13 gpcd), and consumption was assumed to be 15 percent (Annex F) of the total municipal withdrawal (i.e. residential plus commercial plus losses).

The high projection of municipal water use was derived by using the high coefficients with the medium population forecast; the MLP by using the mean coefficients with the medium population forecast; and the low by using the low coefficients with the low population forecast.

MLP Projection

	1975	2035	Annual Growth Rate
Withdrawal (cfs)	930 (7%)	2,400 (1%)	1.6%
Consumption (cfs)	150 (22%)	360 (8%)	1.5%

Seventy-seven percent of the 930 cfs withdrawn in Canada for municipal use is obtained directly from the lakes, the remainder coming from either tributary streams or groundwater sources. Sub-basins will experience

Alternative Projections of Canadian Municipal Water Consumption Total Great Lakes

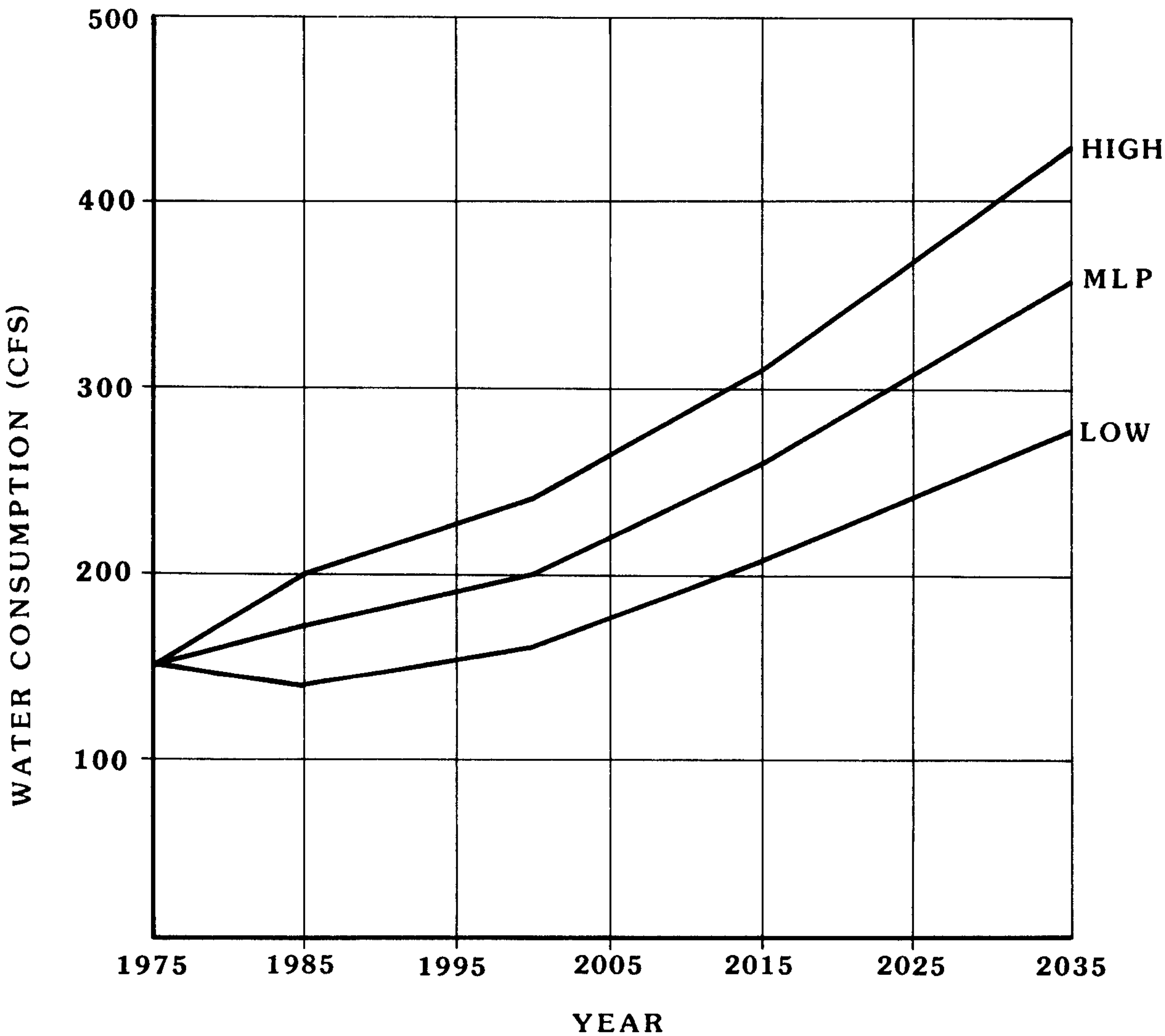


Figure 6-3

different growth rates but the proportion abstracted from the lakes will not change. The Lake Ontario basin accounts for 600 cfs or 66 percent of the total withdrawals of which 550 cfs or 91 percent was withdrawn from the lake itself.

Water consumption is treated as a simple linear function of water withdrawals. Thus the pattern of consumptive use amongst the sub-basins of the study and through time is the same as that described for withdrawal.

High Projection

	2035	Annual Growth Rate
Withdrawal (cfs)	2900	1.9%
Consumption (cfs)	430	

Low Projection

	2035	Annual Growth Rate
Withdrawal (cfs)	1900	1.2%
Consumption (cfs)	280	

Note that under the high and low projections, the withdrawal in 2035 is greater than or less than the MLP by slightly more than 20 percent.

6.2.3 Integration of U.S. and Canadian Data and Discussion

The methodologies used in the two countries are similar for municipal water uses, although some differences in detail are apparent. In both countries, demographic projections prepared by central statistical agencies underlie the water use projections. These demographic projections are based upon anticipated fertility, mortality and migration trends. Regional population is linked with economic activity levels. In both countries, water use coefficients, assumed to be constant through the entire time horizon, were based upon the most recent survey information. These coefficients were computed for each lake basin in the system. Alternative futures, prepared for both Canada and the United States, helped to emphasize the uncertainty factor in water use forecasts.

MLP results for the Canadian and U.S. municipal water use sectors are integrated below and in Table 6-3 and Figure 6-4.

	1975	2035	Annual Growth Rate
Withdrawal (cfs)	7,000 (9%)	13,200 (3%)	1.1%
Consumption (cfs)	830 (17%)	1,600 (6%)	1.1%

Municipal Sector
Consumptive Water Use Projections
Total Great Lakes

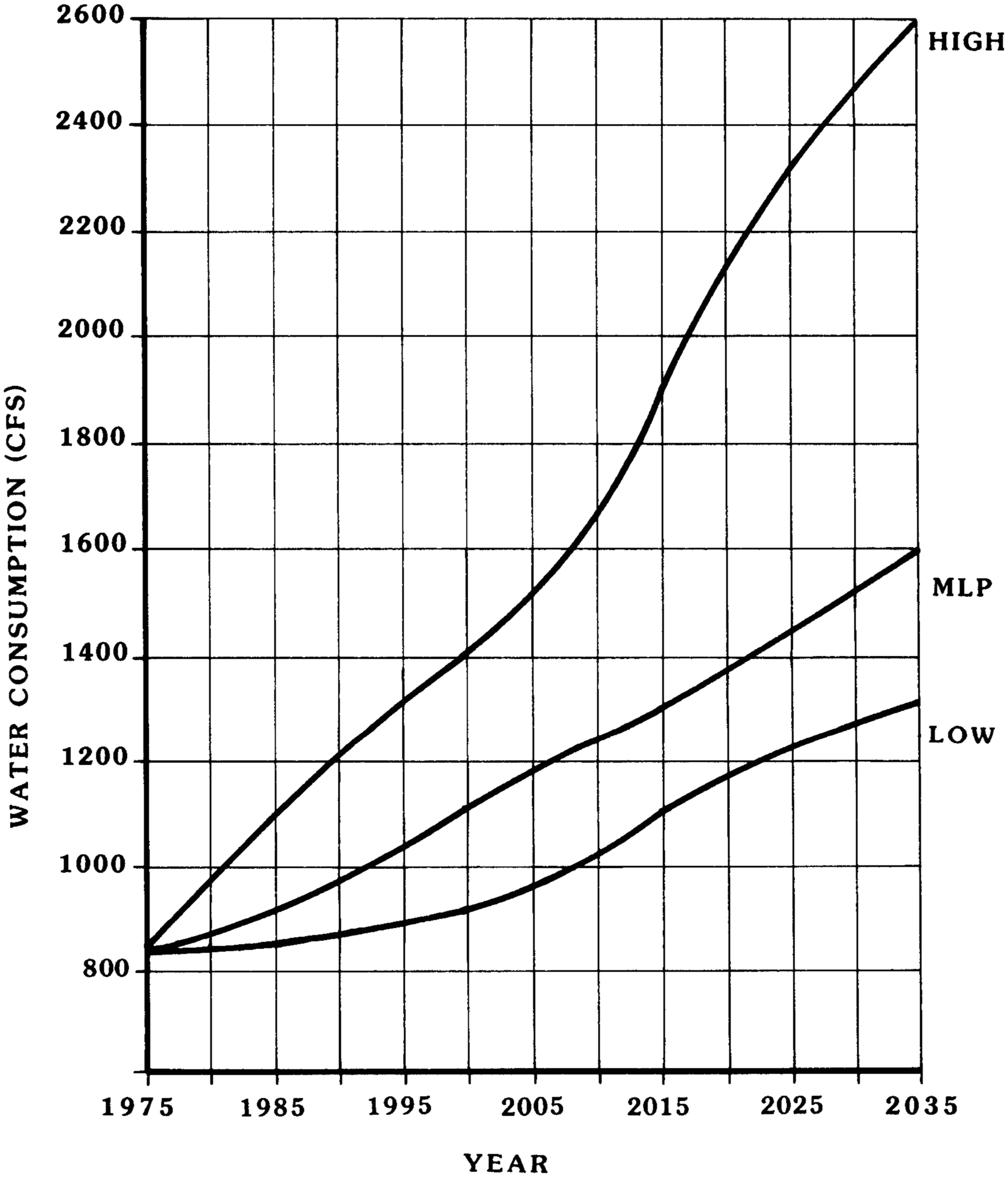


Figure 6-4

In the United States consumption averages about 10 percent of withdrawals, somewhat lower than the 15 percent rate for Canada and also for previous U.S. studies. Consumption rates vary substantially amongst the sub-basins in the United States in contrast to the Canadian rates which have been assumed to be constant. Consumptive uses in the Lake Erie and Michigan basins dominate the U.S. totals; those for the Lake Ontario basin dominate the Canadian totals.

Water use projections for both Canada and the United States increase with time in line with general population growth. Although the Canadian growth rate is higher, the dominance of total water use by the United States is clear. The lower growth rate in U.S. water use, in comparison to the Canadian rate, is directly attributable to the lower rate of population growth. In turn this is related to the lower economic growth rate in the U.S. part of the basin. The difference is rooted in the location of primary growth areas. In the United States, the future high growth areas are projected to be external to the Great Lakes basin. In Canada the basin will continue its central role in the economy, and grow at or near the national rate.

In terms of quantity, the water available is more than adequate to satisfy present and projected municipal needs. The majority of regional water supply problems are associated with the quality of the available water supplies, the cost of treating and transporting this water, and conflicting demands for the water resource.

6.3 Rural-Domestic Water Use

Rural-domestic water uses refer to those non-communal, private water uses usually associated with rural populations. Such uses are most often serviced from groundwater sources.

6.3.1 U.S. Rural-Domestic Water Use

Water required to supply U.S. rural-domestic needs represents the fifth largest water use sector in the U.S. basin.

MLP Projection

	1975	2035	Annual Growth Rate
Withdrawal (cfs)	500 (1%)	600 (0%)	0.3%
Consumption (cfs)	300 (7%)	370 (2%)	0.3%

Although both withdrawal and consumption will increase during the period 1975-2035, the proportion used for rural-domestic use is expected to decrease because of the relative increases in other demand sectors. All water withdrawn for this purpose is supplied by private systems from inland streams, reservoirs or groundwater wells. Water use by the rural-domestic sector has virtually no effect on the levels of the Great Lakes because of the small quantities required.

The population on non-communal private systems in the U.S. portion of the Great Lakes basin is projected to decrease about 35 percent by 2035 from the 5,090,000 persons that were serviced in 1975. However, the use of pressurized as opposed to non-pressurized systems is expected to increase and per capita water use on pressurized systems is expected to increase at least 25 percent. Therefore, even though the serviced population will decrease, the combination of factors results in a net increase in water use during the projection period.

A single rural-domestic water use projection was prepared for this study based on the U.S. Department of Agriculture input to the NAS. The methodology used to obtain the MLP consists of the following steps (Annex F):

(1) An estimate of the number of people served by self-supplied systems in 1970 was determined with 1970 Census of Housing data.

(2) A standard rate of decline between 1960 and 1970, based on Census of Housing data, was determined for each Aggregated Statistical Area (A.S.A.). This rate multiplied by the percentage of units with private, non-communal systems and OBERS-E population forecasts provided projections of the population served by these self-supplied systems.

(3) Per capita rates of rural-domestic water use were estimated for housing units with and without running water under pressure. Average daily per capita use estimates are 40 gallons with pressure and 10 gallons without pressure.

(4) The population projections for pressurized and non-pressurized systems were multiplied by the corresponding per capita withdrawal and consumptive use rates and summed to obtain total withdrawals and consumptive use during the forecast period.

6.3.2 Canadian Rural-Domestic Water Use

Population forecasts were adjusted to include only that portion living in the Great Lakes basin. They were then subdivided into the individual lake basins and further subdivided into rural and municipal components. Rural population (farms plus communities under 1000) totaled 1.1 million persons in 1975. This population generally represents those served by non-communal, private systems. This population is expected to grow between 0.9 percent and 1.1 percent per annum to 1.9 to 2.1 million persons in 2035. Using the population forecasts, rural-domestic water withdrawal was calculated on the basis of a constant factor of 35 gallons per capita per day throughout the forecast period with a consumption rate of 60 percent (Annex F). All withdrawals for rural-domestic purposes are from non-lake sources so the impact on the Great Lakes is reflected in reduced influx rather than direct withdrawal.

MLP Projection

	1975	2035	Annual Growth Rate
Withdrawal (cfs)	60 (1%)	130 (0%)	1.3%
Consumption (cfs)	30 (7%)	80 (2%)	1.7%

As shown in Table 6-2, withdrawals in 2035 are projected to fall between 120 cfs and 130 cfs with the corresponding total consumption between 70 cfs and 80 cfs. The higher of the two projections is the MLP.

The Huron and Erie basins dominate the current rural population distribution, accounting for 67 percent of the total. By 2035, the Ontario basin will replace Erie as the dominant rural basin. A relatively rapid rate of urbanization in the Erie basin will account for this displacement.

6.3.3 Integration of U.S. and Canadian Data and Discussion

The integrated rural-domestic water use statistics based on the MLP are as follows:

MLP Projection

	1975	2035	Annual Growth Rate
Withdrawal (cfs)	560 (1%)	730 (0%)	0.4%
Consumption (cfs)	330 (7%)	450 (2%)	0.5%

As is the case for other water use sectors, there will be an increase in withdrawal and consumption over the projected period, but this use will decline as a proportion of the total use by all sectors.

U.S. and Canadian methodologies are comparable. The lower growth rate in U.S. water use, in comparison to Canada, is primarily attributable to the lower rate of population growth. In turn this is related to the lower economic growth rate in the U.S. part of the basin. Results of the integration of U.S. and Canadian projections for rural-domestic water use are shown in Table 6-3 and Figure 6-5.

6.4 Manufacturing Water Use

The manufacturing water use sector in the Great Lakes basin represents those users traditionally considered as part of heavy industry. Such users may be either self-supplied or supplied from central systems.

6.4.1 U.S. Manufacturing Water Use

Manufacturing is currently second to power generation in terms of magnitude of gross withdrawal, but is the largest consumer of water in the Great Lakes basin (Annex F). Approximately 90 percent of the water requirements are self-supplied while 10 percent are municipally supplied. Specific data based on the MLP are as follows:

MLP Projection

	1975	2035	Annual Growth Rate
Withdrawal (cfs)	20,400 (33%)	27,600 (20%)	0.5%
Consumption (cfs)	2,300 (53%)	7,500 (36%)	2.0%

Rural - Domestic Sector
Consumptive Water Use Projections
Total Great Lakes

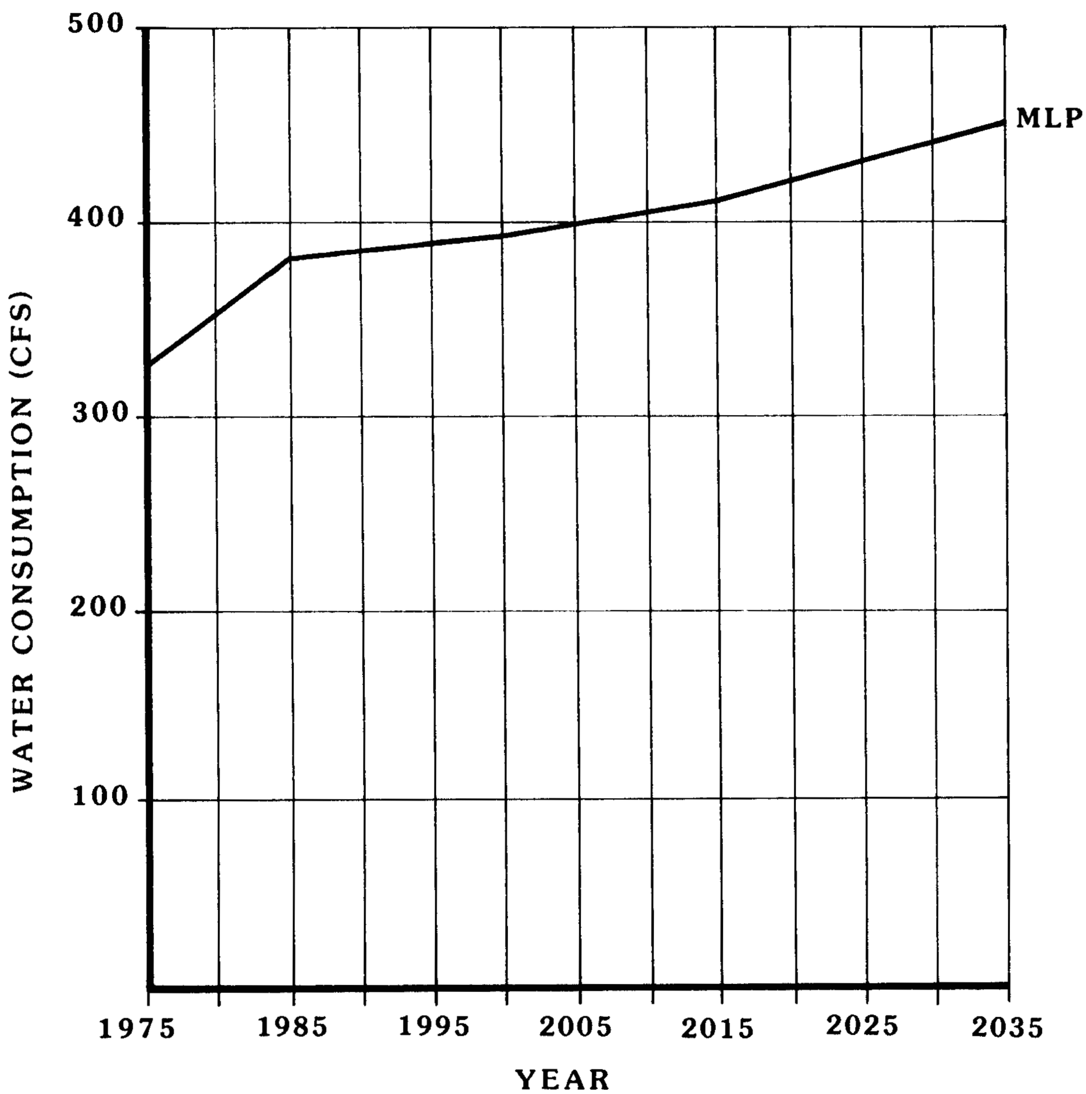


Figure 6-5

Although the data show manufacturing as a major user of water and project an increase in use to 2035, the proportion used by 2035 is expected to decline because of relatively larger uses for power.

Increases in manufacturing consumptive use indicated in the study scenarios are primarily the result of varying assumptions about the institution of closed cycle systems for cooling and process water. The type of system used has generally been dependent upon numerous factors, including water availability and quality, and the degree and cost of effluent pretreatment required. There now is a trend to closed system water recycling as a reaction to mandated water quality standards, water availability and economic feasibility.

Compliance assumptions incorporated into the manufacturing water use projections are based upon the OBERS Series E economic projection of over 100 percent manufacturing growth in the region from 1975 to 2000, which means that about 50 percent of the manufacturing activity in the year 2000 will be generated by plants that do not currently exist.

Four U.S. manufacturing water use scenarios were prepared for this study (Figure 6-6). The primary difference between these sets of numbers is due to varying assumptions about industrial wastewater reuse.

The MLP water use estimates were derived from Projection 3 (NAS) with modification of the P.L. 92-500 compliance assumption as it has been interpreted in the NAS. The NAS presumed that all industries will incorporate the maximum attainable recirculation. However, the MLP was formulated on the assumption that new industry coming on line after 1975 will utilize best available technology for pollution control with associated high recirculation rates, while industry existing in 1975 will continue to use low recirculation rates. The low recirculation rates represent the mean rate for each major manufacturing category; these were assumed to represent best practicable technology for the existing segment of the manufacturing sector. Other assumptions are that: 1) the relationship between water withdrawals and consumptive use for industry existing in 1975 will remain constant throughout the projection period; and, 2) a linear relationship exists between water withdrawals and consumptive use for new industry.

Total manufacturing water use projections are the sum of the increment of new manufacturing water use estimates plus the existing 1975 water use.

Projection 2, the 1978 NAS projection, was prepared by the U.S. Water Resources Council. It is the low estimate of manufacturing withdrawals and consumptive use. The major assumptions used to formulate this projection are 1) the institution of closed cycle water use by the year 2000 throughout the basin, 2) the highest recirculation rate recorded in 1975 for a major water-using industry group will be uniformly adopted by all industry within each group and 3) the primary metals industry will be phased out of the Lake Erie basin.

Alternative Projections of U.S. Manufacturing Water Consumption Total Great Lakes

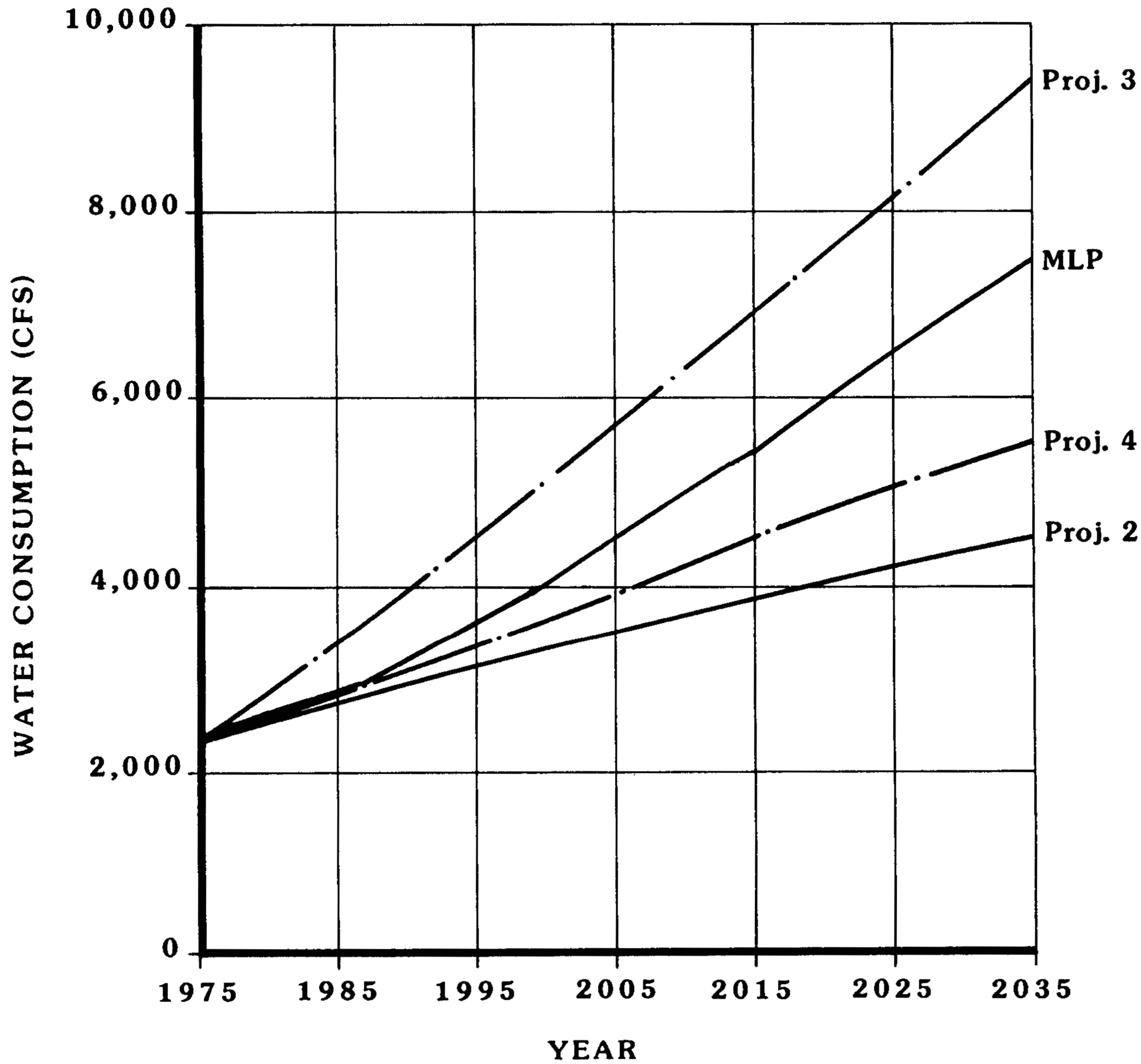


Figure 6-6

Projection 3 was developed with 1978 NAS data with modification of the assumption that the primary metals industry will be phased out of the Lake Erie basin. Lake Erie manufacturing water use estimates in this projection conform to OBERS Series E economic projections. The other assumptions made for Projection 2 apply to these figures.

Projection 4 is based on the assumptions that 1) there will be no additional institution of closed cycle industrial water systems other than those systems in operation in 1975, 2) existing recirculation rates will be maintained through 2035, and 3) the relationship between withdrawal and consumptive use rates will remain constant within each manufacturing group, but the mix of groups will change as in the MLP (Annex F).

6.4.2 Canadian Manufacturing Water Use

In the Canadian economy the Great Lakes basin is the most important industrial area. In 1974, the latest year statistics are available, about 51 percent of the total value of shipments by the Canadian manufacturing sector was accounted for by Ontario industry as well as 49 percent of total manufacturing employment. Furthermore, about 39 percent of Canada's total manufacturing firms were located in the province, including 54 percent of the largest firms.

The Ontario input-output (I-0) table for 1965 was used as the basis for the industrial model (Annex F). On the basis of the 1971 water use information for Ontario as a whole, vectors of water use coefficients were developed. The vectors were used in conjunction with the input-output model to generate estimates of future manufacturing water use. Estimates of growth patterns in the Ontario economy were developed from an analysis of economic data from 1956 to 1975. On the basis of this aggregate analysis, three growth rate estimates were selected to represent low, medium and high scenarios. These sets of growth rates were then used in the model to forecast water use. In addition, a special analysis was carried out on the effect of technological change on water use. The water use data source for manufacturing was an Environment Canada survey of water use for 1972.

For the MLP all water use parameters, except the economic production level, were held constant. Specifically, the technology of water use, as reflected by the use and consumption rates, and the pattern of inter-industry production, as reflected by the technical coefficients of the I-0 model, were assumed constant (Annex F).

The selection of economic growth rates for each manufacturing sector is critical in projecting the MLP. The empirical basis for determining this set of growth rates was the real value of shipments (1971 dollars) data for Ontario since 1950. Although basing long-term growth rates on this period may bias the water use forecasts toward the high side, the economic statistics from this period had to be used for they are the best data available. The 25-year period was split into five-year segments. Compound annual growth rates for each period were then calculated, and high, medium and low rates were formulated. It was assumed that growth in each industry would reflect the medium rate of growth to 1985, the low rate of growth past 2000 and the average of these two rates between 1985 and 2000.

Specific manufacturing water use statistics based on the MLP are as follows:

MLP Projection

	1975	2035	Annual Growth Rate
Withdrawal (cfs)	5,600 (41%)	49,400 (20%)	3.7%
Consumption (cfs)	220 (35%)	2,000 (45%)	3.8%

Of the various Canadian users in this sector, chemicals, pulp and paper and primary metals will continue to be the largest users with chemicals, petroleum and coal experiencing the most rapid rates of increase. The Lake Ontario, Lake Erie and Lake Huron basins, in descending order, will continue to be responsible for most of the region's water withdrawal and consumption. The latter two basins contain the industries projected to grow most rapidly.

Five alternative projections to the Canadian MLP of manufacturing water use were developed (Figure 6-7; Annex F). The first alters the growth rate for each manufacturing category from the MLP to the high, medium and low rates. The high and low scenarios set upper and lower limits on the MLP. The second alternative uses a set of constant growth rates based on the last 25 years. The third alternative simulates changes in the technological assumptions about water use by altering the use and consumption rates. The fourth alternative shows what would happen to water intake and consumption in the Canadian section of the basin if the rates for Canada took on the values assumed in the U.S. compliance with the Clean Water Act. The last alternative combines the growth rate alternatives with the medium technological change alternative to simulate water use under a complex set of future assumptions (Annex F).

Because water use data collection in Canada is relatively recent, insufficient measurements exist to allow a statistical approach to the forecasting exercise. The simulation approach taken here is an alternative and allows the selection of a range of water use estimates around the MLP; it is improbable that future manufacturing water use will fall outside the indicated band. Trends in environmental control, even in Canada, will induce more recirculation (i.e. higher use rates) in the future with attendant increases in water consumption. From Figure 6-7 it is apparent, given the exponential nature of the water use model, that the degree of uncertainty increases with time.

6.4.3 Integration of U.S. and Canadian Data and Discussion

The U.S. and Canadian approaches to forecasting manufacturing water use are similar in most aspects. In both countries the base year data were obtained by direct surveys of individual plants. The format and definitions employed on survey work is similar, making the basic water use data comparable. Coefficients of water use were calculated using base year relationships between water use and productivity in both countries. These coefficients were assumed constant within manufacturing groups through the entire forecasting horizon in both countries. However, in

Alternative Projections of Canadian Manufacturing Consumption

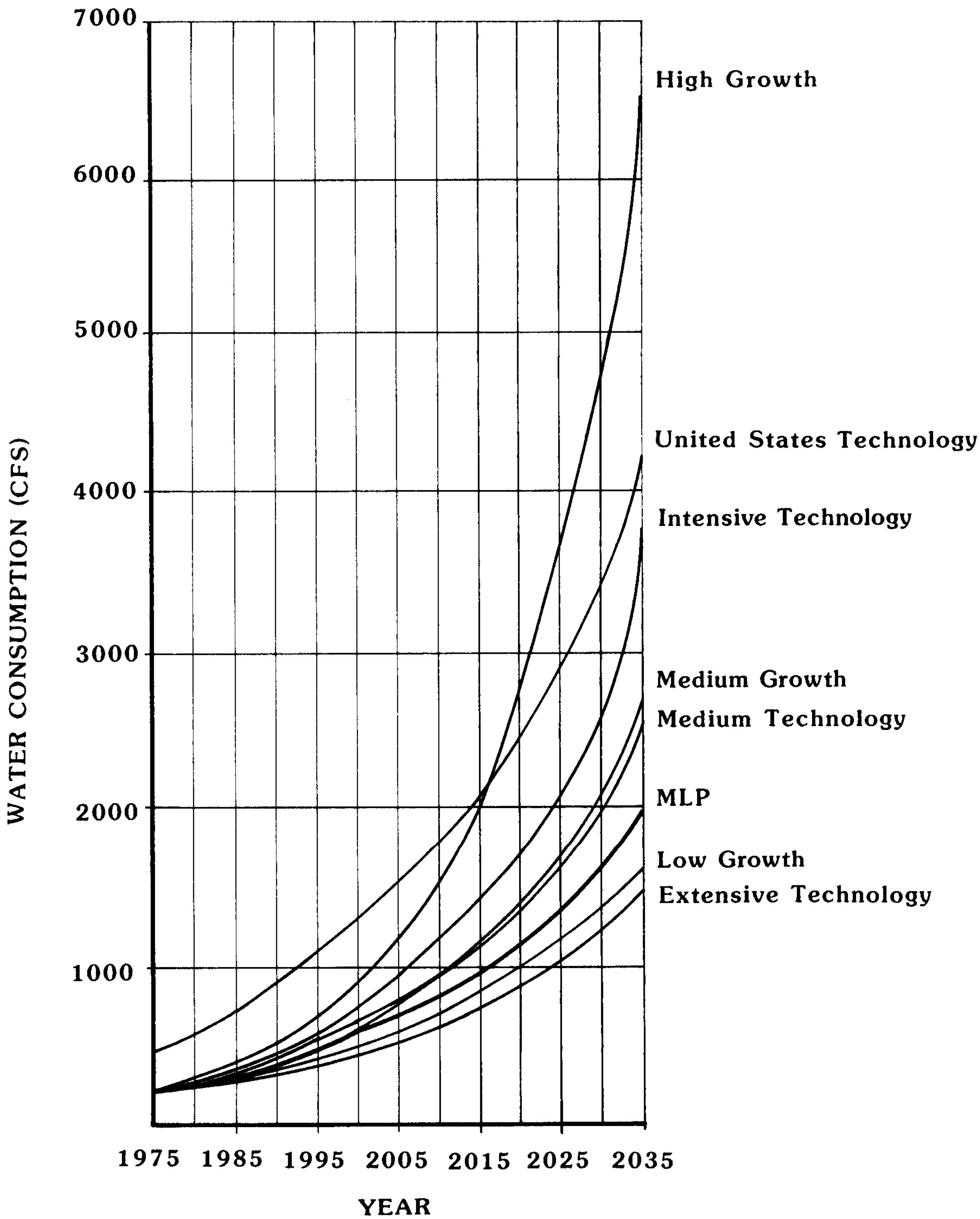


Figure 6-7

Canada, water withdrawals and consumption were the parameters treated in this manner; whereas the "coefficients" approach applies only to gross water use in the United States. In both countries only one economic parameter, output value, underlies the forecasts.

The substantive differences in approach centre around two issues: parametric variation in recirculation and consumption rates, and the method of formulating sub-basin estimates. The U.S. MLP assumes that new industries will incorporate the best available technology to meet the requirements of the Clean Water Act. These requirements imply higher recirculation and consumption rates. In contrast, the Canadian MLP holds recirculation and consumption rates constant. The second point of departure relates to the comparative detail of sub-basin forecasts. In the U.S. study, forecasting was done initially for the basin as a whole, and later a more detailed disaggregation into sub-basins was prepared by using current distribution proportions. Such a disaggregation was not undertaken for the Canadian study. Although some differences exist in the assumptions, the forecasts for the two countries can be reasonably compared providing that the recirculation and consumption rate assumptions for the United States, which are based on environmental considerations, are kept in mind.

For the manufacturing sector, the relatively small increase in U.S. water withdrawals (MLP) from 20,400 cfs in 1975 to 27,600 cfs in 2035 and the relatively large increase in consumption are notable (Table 6-1). Withdrawal and consumptive use rates will primarily reflect technology rather than productivity as new plants coming on line conform to pollution control requirements. Canada, much the smaller economic unit, actually will account for a larger volume of water withdrawal than the United States by 2015. However, the United States will continue its dominance of total consumption because of environmental controls and its higher volume of output, although actual quantity will decrease from about 10 times to four times Canadian consumption during the forecast period.

The projected rate of industrial expansion in the United States is somewhat lower (1.6 percent per annum) than that for Canada (3.7 percent). This two percent difference in the industrial growth rate between the two countries can be explained. Historically, the industrial growth rate of Ontario has tended to equal or exceed the corresponding rate for Canada. For example, between 1950 and 1975, the industrial value of shipments (in constant dollars) in Canada grew annually at 4.3 percent. The corresponding rate for Ontario was 5.5 percent. Empirically, Ontario, and the Great Lakes basin in particular, has experienced growth at or above national rates.

Over the short term, industry in western Canadian areas, such as central and southern Alberta and parts of Saskatchewan, will likely expand faster than Ontario because of their fossil fuel energy resources. However, it is still problematic whether this primary sector growth will result in sustained high industrial growth and eventual economic dominance. First, western markets are small and some industrial sectors, favouring locations close to large markets, will likely stay in Ontario with ready access to the United States. Second, transportation costs to bring manufactured goods from the west tend to be high. These factors are against massive industrial expansion. Third, heavy industry requires substantial amounts of water and, although this requirement is not absolute, it needs large advantages to offset the degree of recirculation necessary under semi-arid conditions. The west may not have these. Therefore, the approach is taken that Ontario will continue to occupy an important place in the industrial economy and will grow at or near the national rate. Thus over the long run, a 3.5 to 4.0 percent rate of expansion is feasible. Because a direct correlation is assumed between industrial growth and water use, the 3.7 percent increase in consumptive use is also feasible.

In contrast, the U.S. forecasts for the basin are based upon projections for the country as a whole, and, once the national forecasts are established, the breakdown into regional forecasts is fairly mechanistic. The approach used in this disaggregation, shift-share analysis, is legitimate, having been well-established in regional economic theory. Because the basin's growth rate has been below the national average in the past 25 years, and because the region has a large number of the slower growth industries, the projected rate of growth is lower than the U.S. economy as a whole, lower than that for Ontario. According to the OBERS Series E projections, the average growth rate nationally will be 2.9 percent per annum, while that for the basin will be 2.7 percent. In effect, other areas of the U.S. economy, notably the south and southwest are predicted by OBERS to experience the highest rates of growth over the next 50 years. This forecast has been made largely on the basis of past trends in the shift-share ratios and it ignores the water shortage problems of the southwest. In reality, this region may not be able to sustain high growth rates over the long run which may ultimately result in higher growth in more humid areas, among them the Great Lakes basin with its tremendous water resource availability and large markets.

In summary then, the two percent difference in the projected consumptive use rate between Canada and the United States is attributable to two factors: 1) the United States foresees future high growth areas to be in the south and southwest, while Ontario industrial growth will continue at a high rate, being the industrial heartland of Canada, and 2) the existence in the United States of a more mature industrial base. Results of the integration of U.S. and Canadian manufacturing projections are shown below and in Table 6-3 and Figure 6-8.

MLP Projection

	1975	2035	Annual Growth Rate
Withdrawal (cfs)	26,000 (34%)	77,000 (20%)	1.8%
Consumption (cfs)	2,500 (51%)	9,500 (37%)	2.2%

Manufacturing Sector
Consumptive Water Use Projections
Total Great Lakes

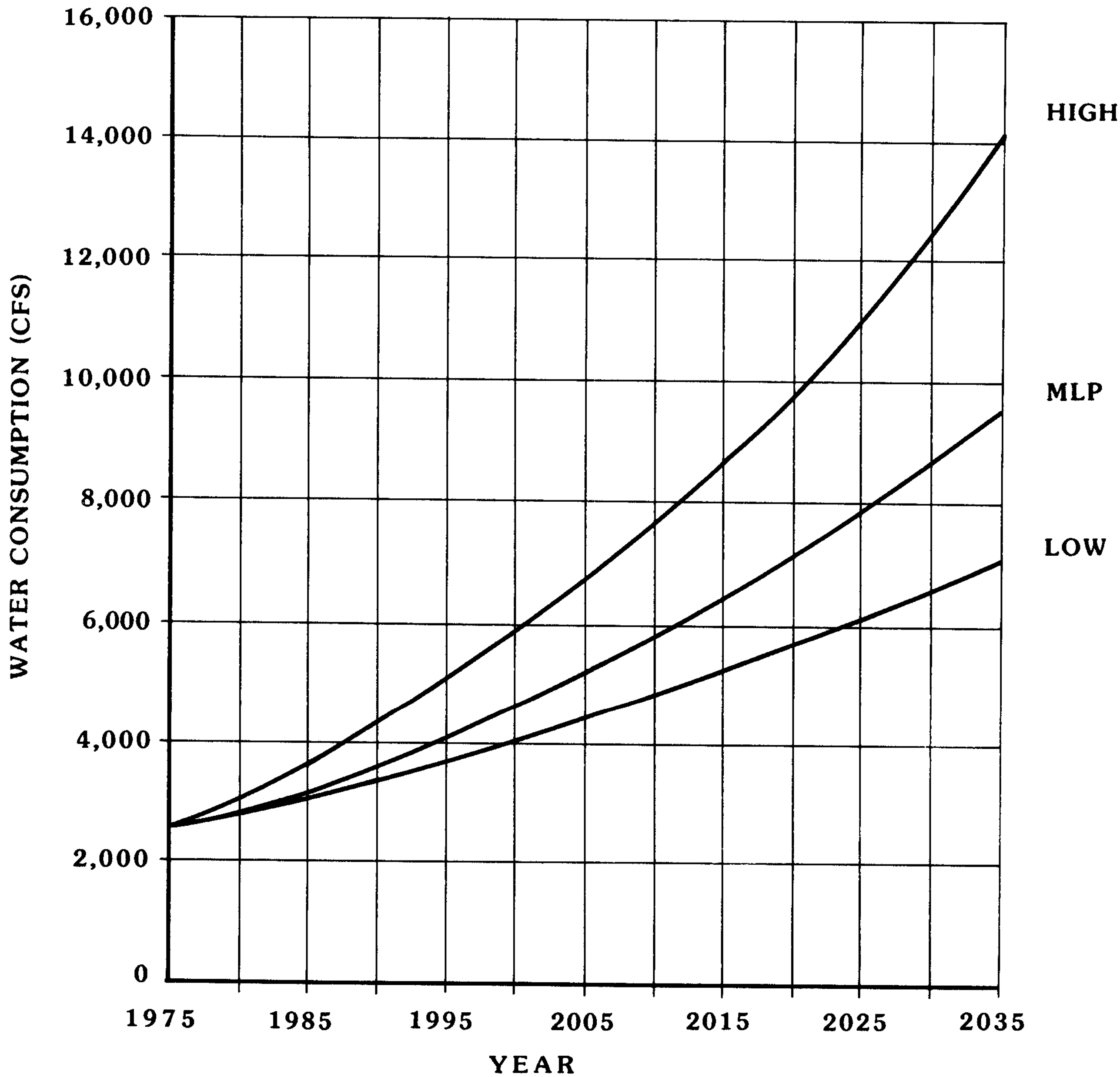


Figure 6-8

6.5 Mining Water Use

Mining water use in the Great Lakes basin involves supply of water to a variety of mining processes including metals, non-metallic minerals, coal, petroleum, and natural gas.

6.5.1 U.S. Mining Water Use

Metals, non-metals and mineral fuels are mined in the Great Lakes region, although only iron ore is mined in large quantities. Most of the national production of iron ore comes from the basin.

The Great Lakes provide about 80 percent of U.S. mining water requirements. Although much of the water withdrawn for mining purposes is returned to the lakes, some water is lost to surface infiltration and evaporation. Specific mining water uses are as follows:

MLP Projection

	1975	2035	Annual Growth Rate
Withdrawal (cfs)	1,100 (2%)	2,400 (2%)	1.3%
Consumption (cfs)	240 (6%)	460 (2%)	1.1%

The proportional drop in consumption from 6 percent in 1975 to 2 percent in 2035 is because of conversion to recycling technologies and increased consumption in other sectors. The 1.1 percent compounded growth rate is slightly less than the projected economic growth rate for this sector.

The projections developed for the NAS mining water requirements are presented as the single scenario for water use by the mining sector (Annex F). No other projections were generated for this study. Even if a large variance is allowed in the mining estimates, this sector's relatively small water consumption would have no significant effect on lake levels.

Estimates of mining industry water requirements in the Great Lakes region, based on the standard water use rates and consumption percentages as applied to the OBERS Series E mineral earnings, were developed by the U.S. Bureau of Mines (USBM)(Annex F). Projections of mineral industry water withdrawals and consumption were obtained by extrapolating the USBM data to 2035.

6.5.2 Canadian Mining Water Use

The Canadian mining sector is economically strong with activity centered in the Canadian Shield area of the upper lakes. The mining growth rates for the MLP were selected in the same manner as those for manufacturing. The resulting water withdrawal and consumptive use forecasts were formulated and aggregated by basin on the basis of basin shares of productivity and mine type.

MLP Projection

	1975	2035	Annual Growth Rate
Withdrawal (cfs)	130 (1%)	1,200 (0%)	3.8%
Consumption (cfs)	0 (1%)	40 (1%)	3.9%

In Canada, most of the water used for mining purposes is obtained from non-lake sources in the Lake Huron basin.

6.5.3 Integration of U.S. and Canadian Data and Discussion

Methodologies for developing both U.S. and Canadian figures are based on water use per production dollar within each mineral classification and projections are tied to the separate economic climates; therefore, the methodologies are deemed comparable. The figures developed for the combined Great Lakes mining sector MLP are shown below and in Table 6-3 and Figure 6-9.

MLP Projection

	1975	2035	Annual Growth Rate
Withdrawal (cfs)	1,200 (2%)	3,600 (1%)	1.8%
Consumption (cfs)	240 (5%)	500 (2%)	1.2%

6.6 Rural-Stock Water Use

Rural-stock water use refers to the withdrawal and consumption of water for the feeding and sanitation of livestock. Livestock consumptive use includes losses of animal drinking water, evaporation from stockwater ponds and losses of cleaning and waste water. All of this water will be derived from upland sources. Categories of livestock include beef cattle, dairy cattle, pigs, sheep and poultry.

6.6.1 U.S. Rural-Stock Water Use

Alternatives were not developed because of the negligible quantities of water used for this purpose. The following procedure was used in the NAS to generate the MLP water use data shown in Table 6-1.

(1) Estimates of livestock production were derived from the OBERS Series E projections of human population which were translated into historical trends of commodity demands. Projected livestock production was allotted throughout the region on the basis of the population projections.

(2) Livestock water use estimates by category were calculated as a function of stock water use rates and livestock production figures.

(3) The relationship between numbers of livestock and associated commodities produced were estimated for each region with data from 1970 Agriculture Census reports.

Mining Sector
Consumptive Water Use Projections
Total Great Lakes

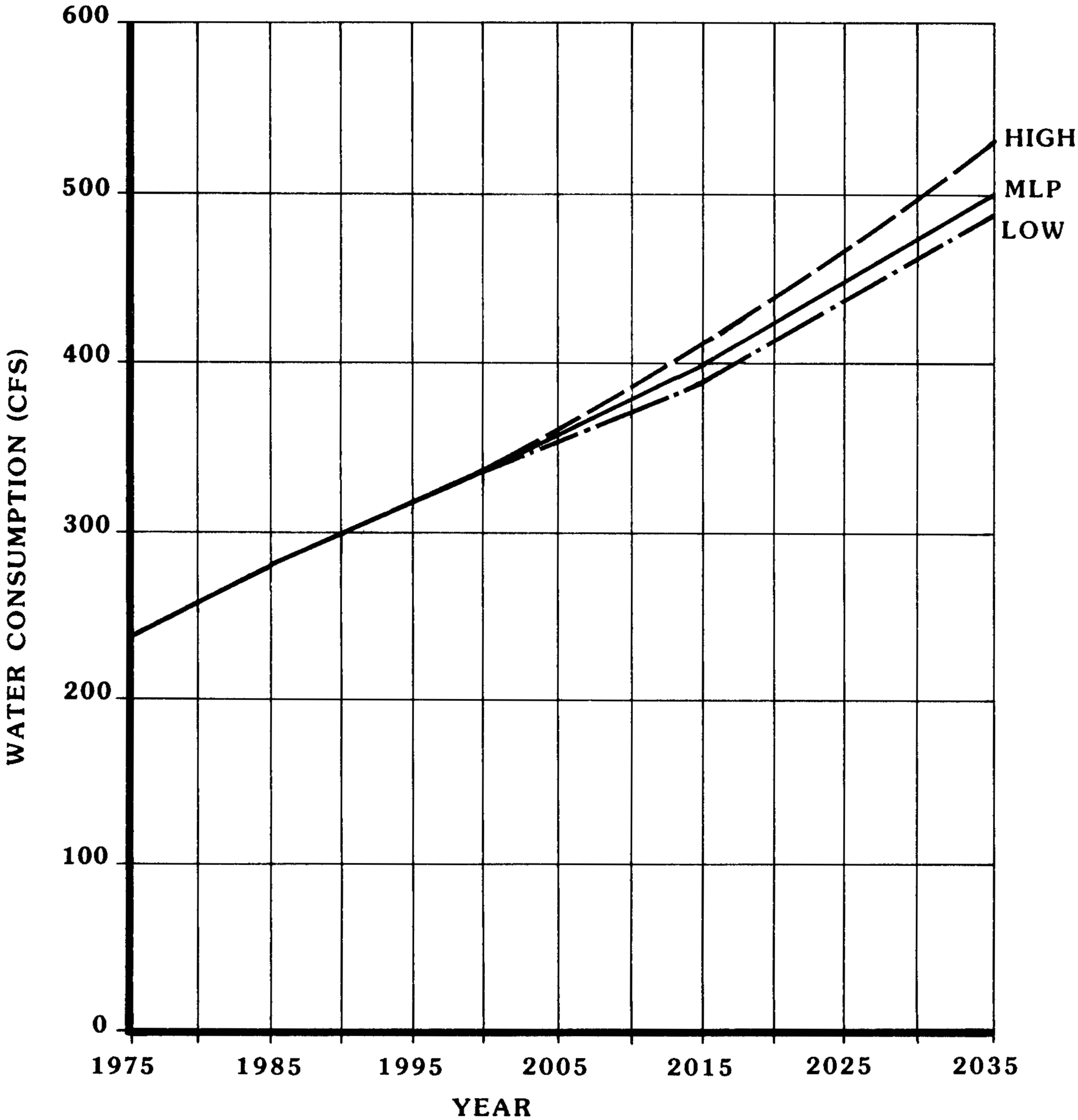


Figure 6-9

(4) The projected annual livestock water requirements°for the period 1975-2000 were determined by multiplying the stock water use rates by the projected livestock production figures. Consumptive use rates are assumed to be 100 percent of withdrawal rates. This may not be true in all cases of stock water use, but estimates of return flow are tenuous and the magnitude is considered negligible in the context of this study. Projections for the period 2000 - 2035 were derived by extrapolation.

These figures for the rural stock watering sector were developed by the U.S. Department of Agriculture.

MLP Projection

	1975	2035	Annual Growth Rate
Withdrawal (cfs)	130 (0%)	140 (0%)	0.1%
Consumption (cfs)	130 (3%)	140 (1%)	0.1%

6.6.2 Canadian Rural-Stock Water Use

Projections of livestock water use involve a forecast of the number of animals by category. It was assumed that dairy and meat products from Ontario livestock were destined for Ontario markets; no account was taken of either exports or imports. In forecasting the number of animals by category, the variable used was per capita consumption of meat products, statistics which are available back to 1939; a time series from 1945 to 1977 was used for this study. The procedure involved regression analysis with time as the independent variable.

Once the per capita consumption values were derived, they were multiplied by the forecasted "medium" population and then divided by the average animal weights to give a predicted number of animals in the basin for each future year. The number of animals was then used as the basis for the water use forecast for each class of animal. Disaggregation of the total livestock water use was based on available data extending back to 1931. All water withdrawals for stockwater are considered to be consumed.

The estimates of livestock distribution among each lake basin in 1975 (Annex F) were multiplied by the water use coefficients and then aggregated into water withdrawals and consumption.

MLP Projection

	1975	2035	Annual Growth Rate
Withdrawals (cfs)	80 (1%)	220 (0%)	1.7%
Consumption (cfs)	80 (13%)	220 (5%)	1.7%

In developing alternative Canadian projections, high and low estimates were computed using meat and dairy consumption figures 20 percent above the MLP and 20 percent below the MLP respectively, with the appropriate population projection.

Withdrawals & Consumption (cfs)

	1975	2035	Annual Growth Rate
High Forecast	80	270	2.0%
Low Forecast	80	170	1.2%

6.6.3 Integration of U.S. and Canadian Data and Discussion

The only fundamental difference between the U.S. and Canadian methodologies is consideration in the Canadian forecasts of per capita meat and dairy product demand to estimate numbers of animals. The U.S. methodology projects the number of animals in various categories on the basis of human population growth rates and presumes a linear relationship with demand. Distribution of livestock among basins was done on the basis of population distributions. This factor will have a small impact upon the overall comparability of the forecasts. As in the Canadian methodology, all rural-stock water is counted as being consumed. Projections for the rural-stock sector are shown in the Figure 6-10 and Table 6-3. Specific data for the integration of stock watering based on the MLP are as follow:

MLP Projection

	1975	2035	Annual Growth Rate
Withdrawal (cfs)	210 (0%)	360 (0%)	0.9%
Consumption (cfs)	210 (4%)	360 (1%)	0.9%

6.7 Irrigation Water Use

Irrigation water use refers to the withdrawal and consumptive use of water for the watering of crops, pastures, orchards, golf courses and public lands such as parks, forests and other similar lands. All of this water is obtained from inland sources.

6.7.1 U.S. Irrigation Water Use

Water withdrawals required for irrigating cropland, golf courses and public lands comprise the sixth ranking (of seven) demand sector in the U.S. Great Lakes basin. Relatively small quantities of water are needed for this purpose as compared to national averages because of the normally abundant rainfall in the region. Specific irrigation uses based on the MLP are as follows:

MLP Projection

	1975	2035	Annual Growth Rate
Withdrawal (cfs)	350 (1%)	940 (1%)	1.7%
Consumption (cfs)	260 (5%)	790 (3%)	1.9%

Even though cropland acreage will stabilize, threefold increases in water demand are projected by 2035; however, the rate of consumption will fall to three percent because consumption in other use sectors will increase significantly.

Rural - Stock Sector
Consumptive Water Use Projections

Total Great Lakes

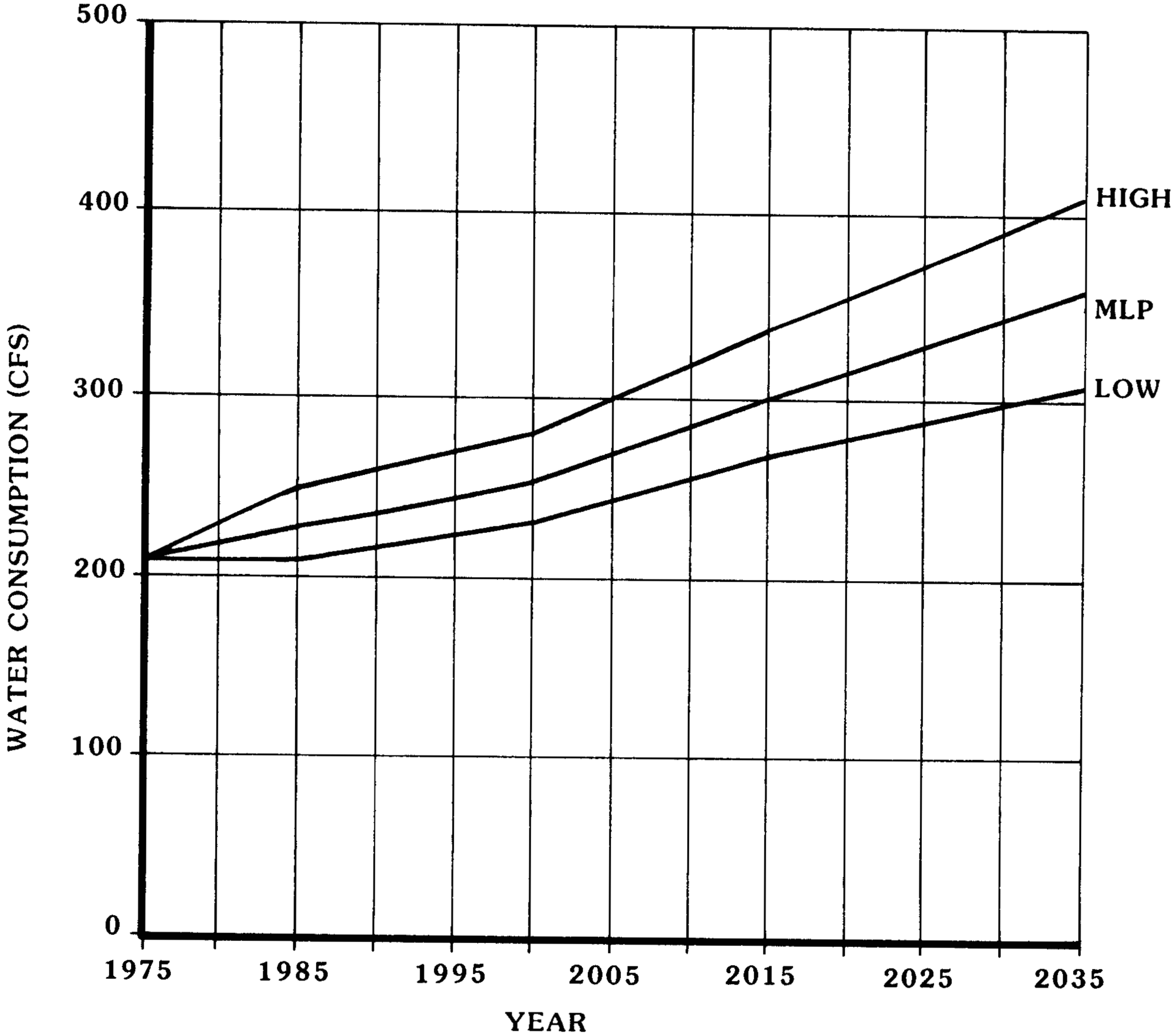


Figure 6-10

Agricultural consumptive use varies with the type of application, topography, climate, condition of soils and kind of vegetation. Estimates of water consumption were developed according to crop type for agricultural irrigation and calculated usage rates. Consumption ranges between 72 percent and 85 percent of withdrawals. The figures for agricultural water withdrawals and consumption were developed by the state offices of the U.S. Department of Agriculture and the Soil Conservation Service (SCS) for the NAS.

Golf course irrigation constitutes the primary recreational water demand. The aggregated estimate of golf course construction is based on OBERS Series E population projections, use of existing facilities and anticipated demands within A.S.A. Factors affecting water consumption vary geographically; however, basin-wide average water consumption at 75 percent of withdrawals has been used in this study.

Consumption statistics for crops and golf courses are as follows:

	1975	2035
Crops		
Consumption (cfs)	180	630
Golf Courses		
Consumption (cfs)	80	160

Projections of water use in the public lands are based on OBERS Series E population projections. The figures were derived by extrapolation of historical demand and past uses based on expected administrative and resource management plans. They are about six percent of the irrigation sector. One hundred percent of water withdrawals for public lands irrigation is assumed to be consumed. The irrigation projections (Table 6-1) are the sum of the agricultural, recreational and public land projections.

6.7.2 Canadian Irrigation Water Use

Few data exist on irrigation water use in Ontario. Statistics Canada commenced publication of irrigated acreages as recently as 1960 on a 10-year time interval. Using the compound growth rate between 1960 and 1970, irrigated acreages were updated to 1975 (about 110,000 acres). For all counties wholly or partly within the Great Lakes basin, for which irrigated acreages were reported, it was assumed that 100 percent of the acreage was contained within the basin. Using an average coefficient of 5.87 inches of water per acre (Annex F), the land area was converted to water use. Irrigated areas were allocated amongst sub-basins on the basis of population distribution. This procedure was adopted in the absence of any better distributional data. Consumption for crop irrigation was assumed to be 50 percent of withdrawal, based on a report by the Montreal Engineering Company (Annex F).

Specific data for irrigation in Canada based on the MLP are as follows:

MLP Projection

	1975	2035	Annual Growth Rate
Withdrawal (cfs)	130 (1%)	330 (0%)	1.6%
Consumption (cfs)	90 (15%)	240 (5%)	1.5%

In Ontario the major irrigated crops consist of tobacco, fruit and vegetables. However, the irrigation of other crops may take the place of tobacco agriculture. Assuming that the growth in demand for irrigated crops is related to population growth, irrigation water use is projected on the basis of the medium population scenario.

Shown below are specific data dealing with crop irrigation in Canada based on the MLP and data on golf course irrigation taken from Ontario Ministry of the Environment (MOE) records and the Ontario Golfers Association. For golf course irrigation, consumption is assumed to be 100% of withdrawal.

	Withdrawal (cfs)		Consumption (cfs)	
	1975	2035	1975	2035
Cropland	70	190	30	100
Golf Courses	60	140	60	140
	130	330	90	240

Cropland irrigation is centered in the Lake Erie basin which accounted for about 75 percent of the total water withdrawal in 1975.

To demonstrate sensitivity of the Canadian irrigation MLP to changes in assumptions, low and high estimates of irrigation were made as follows:

High forecast with 20 percent more land than MLP (cfs)

	Withdrawal	Consumption
	2035	2035
Cropland	220	110
Golf courses	190	190
	410	300

Low forecast with 20 percent less land than MLP (cfs)

	Withdrawal	Consumption
	2035	2035
Cropland	160	80
Golf courses	130	130
	290	210

6.7.3 Integration of U.S. and Canadian Data and Discussion

The MLP for the Great Lakes basin indicates that irrigation water use, representing about one percent of total withdrawals in 1975 and seven percent of total consumption will decline to less than one percent of withdrawals and four percent of consumption in 2035. The Lake Michigan basin dominates the U.S. irrigation water use, accounting for 60-65 percent of withdrawals for the time period. The Lake Erie basin dominates the Canadian section at 54 percent of withdrawals. The figures for the combined Great Lakes irrigation sector MLP are shown below and in Table 6-3 and Figure 6-11.

MLP Projection

	1975	2035	Annual Growth Rate
Withdrawal (cfs)	480 (1%)	1,300 (0%)	1.8%
Consumption (cfs)	350 (7%)	1,000 (4%)	1.9%

For irrigation, the extensive data base in the United States made possible a more complex statistical treatment. Application of the Spillman function, a curvilinear regression model developed for the U.S. Department of Commerce that projects yields to increase at a decreasing rate over time, is probably realistic; whereas the Canadian irrigation use figures, based on linear extrapolation through the projection period, are probably biased toward the high side. However, the Canadian consumption rates are a fraction of a percent lower than those for the United States because different withdrawal/consumption ratios are used in the two countries. The overall impact of methodological differences is judged to be small and, in view of the small quantities involved, have a negligible effect on the overall forecasts (Table 6-3 and Figure 6-11).

6.8 Power Generation Water Use

Power generation water use in the context of this report refers only to those water users associated with thermal-electric power production. Hydropower has not been considered here because water consumption is insignificant.

Water is consumed in the thermal generation process in two principal ways. In the first, water introduced into a boiler is converted to steam

Irrigation Sector
Consumptive Water Use Projections
Total Great Lakes

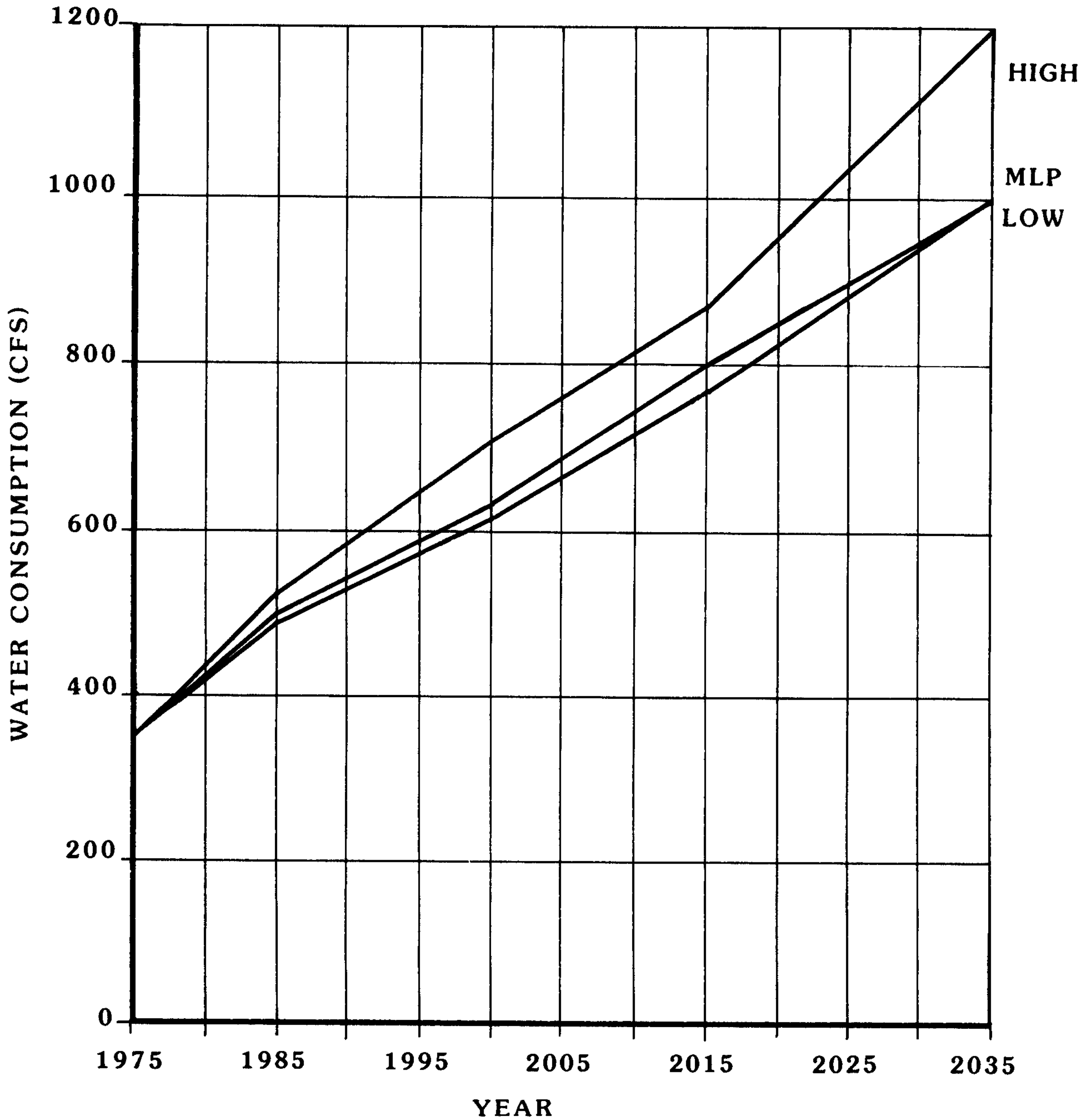


Figure 6-11

to drive the turbogenerator, then passed through a condenser where it is converted back into water. A small amount of water is lost in this recirculation process.

In the second, a large separate flow of water is passed over condensers to carry away the waste heat of condensation. This is the way in which most of the water is lost when returned to the source at higher than ambient temperature or when passed through cooling towers or plants in the closed-cycle systems required to eliminate discharge of heated water. The amount of water required for cooling depends on the type of power plant, its operating efficiency, type of condenser cooling system and the standard temperature rise within the condenser. The type of condenser cooling system is a major factor controlling the relative quantities of water withdrawals and consumptive use. In the extreme, radiator-type closed-circuit cooling towers could virtually eliminate the need for large quantities of cooling water.

6.8.1 U. S. Power Generation Water Use

Water required for thermal-electric power generation currently represents the largest demand on water resources within the U.S. Great Lakes basin. Specific data based on the MLP are as follows:

MLP Projection

	1975	2035	Annual Growth Rate
Withdrawal (cfs)	33,500 (54%)	94,700 (69%)	1.8%
Consumption (cfs)	420 (10%)	10,500 (50%)	5.5%

Water withdrawals for power use constituted 54 percent of the total water withdrawn in the region in 1975 and are projected to increase to about 69 percent by 2035. Existing environmental restrictions keep this percentage from being larger.

Historically in the generation process, water has been consumed in small quantities in relation to withdrawals. Water consumed by the power sector in 1975 constituted only about 10 percent of the total water consumed in the basin. However, consumption is projected to increase to about 50 percent by 2035 because of the institution of controlled water use technology in compliance with the Clean Water Act. Closed-cycle cooling systems are expected to be installed in most of the new generation plants that are under construction or planned to be built by the year 2000 (Annex F).

Assumptions concerning both the mix of power plant types and condenser cooling systems are key factors in the derivation of water use projections; either of the two could be adopted. The mix of nuclear- and fossil-fueled power plants in the MLP is assumed to be of secondary significance after the year 2000. Development of nuclear generating capacity is a controversial public issue and resolution is not apparent. Projections that were made in 1970 are already completely off mark. Based on recent trends, documentation could be found to support projections differing by as much as 60 percent by the year 2020. Nuclear plants presently consume 50 percent more water than comparable fossil-fueled plants so the mix of plants is generally considered to be most critical in estimating consumptive use. However, technology already exists for reducing consumptive water use in nuclear power generation although it may not be economical in today's market. It is obvious then that the estimation of the future mix would be completely arbitrary whereas projection of improved water use efficiency is based on logic. Because increased efficiency would virtually negate the significance of mix, the projection of a uniform mix of plants after the year 2000 rather than projection of 1975 technology was adopted (Annex F).

The existing mix and assumptions about the projected mix of condenser cooling systems are based on information from the NAS and GLBC reports, the Chicago office of the Federal Energy Regulatory Commission, the MAIN Reliability Council office and the Atomic Industrial Forum.

Historically, virtually all power plants have utilized once-through cooling systems in which large quantities of water are withdrawn for cooling purposes with over 90 percent return flow. The implementation of P.L. 92-500 instituted a trend to the use of closed-cycle cooling systems to eliminate environmentally harmful heat discharges.

Available information indicates that 78 percent of the plant capacity currently under construction and scheduled to be on line by 1990 will have closed-cycle cooling systems, whereas 12 percent of existing capacity has incorporated closed-cycle cooling.

The Clean Water Act includes a provision which allows utilities to maintain a once-through cooling system at a particular plant if they can show evidence that no adverse environmental impacts will result. Thus, the trend toward closed-cycle cooling in new plant capacity could be delayed or changed in the future because of concern regarding the high energy demands in such systems or because of a relaxation of environmental restrictions. However, such an occurrence is not clearly indicated at this time.

Six water use scenarios are presented for the U.S. power sector (Figure 6-12). Each of the scenarios indicates that this sector will be a major water consumer. Much of this water will be obtained directly from the Great Lakes. The lake sources are favoured by the power utilities because of their abundant water supplies, the location of power markets around the lakes and the diminished severity of environmental impacts relative to most other sources. The major assumptions distinguishing these water consumption projections are population projections, the growth rate of energy requirements, the mix of power plant types and the type of cooling systems used in the power generation process.

The primary assumptions used to formulate the MLP are: 1) an average annual power growth rate of about 4.1 percent prior to 1980 as indicated in available data bases, 4.7 percent between 1980 and 2000, and four percent

Alternative Projections of U.S. Power Water Consumption Total Great Lakes

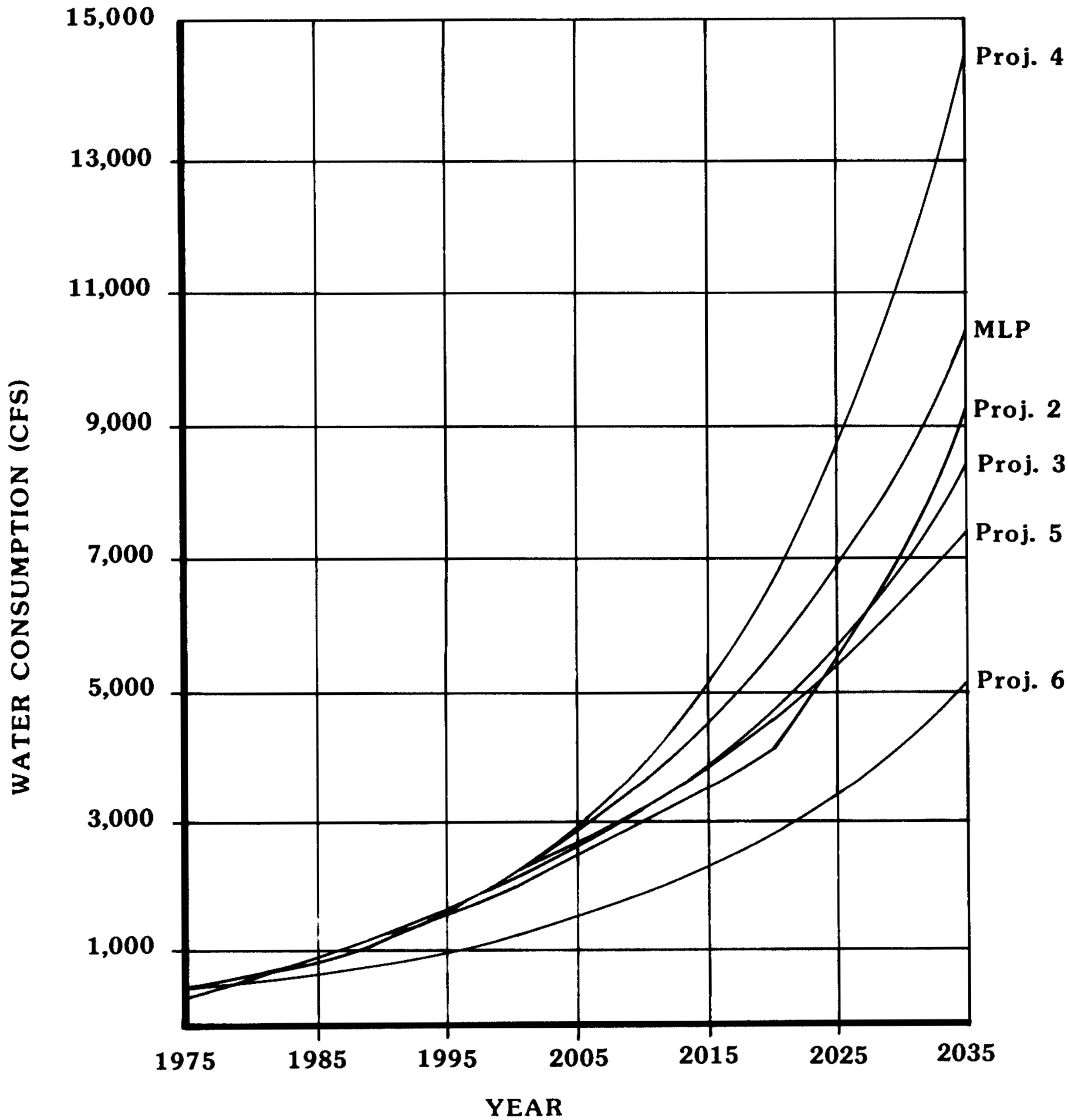


Figure 6-12

from 2000 to 2035; 2) institution of closed-cycle cooling in 78 percent of new power plants between 1980 and 1990 and in 90 percent of the plants constructed after the year 1990; 3) nuclear power production will increase from seven percent of the total in 1970 to 39 percent by 2000; 4) nuclear water use rates of post-2000 construction will equal fossil rates; and, 5) OBERS-E population forecasts.

Projection 2 was extracted from the GLBC Framework Study. The primary assumptions used in the formulation of this projection are: 1) an annual power growth rate of 5.25 percent throughout the projection period; 2) OBERS-C population forecasts; 3) institution of closed-cycle cooling throughout the power system by the year 2020; 4) nuclear power production will increase from seven percent of the total in 1970 to 98 percent by 2020; and, 5) improvements in technology will reduce nuclear water use rates to those of fossil plants by 1985.

Projection 3 is the NAS power water use projections. The primary assumptions used in that study are: 1) an average annual power growth rate of about 6.4 percent from 1975 to 1985, an average rate of 6.1 percent from 1985 to 2000, and a four percent rate from 2000 to 2035; 2) an increase in closed-cycle cooling in steam-electric generating plants from seven percent in 1975 to 87 percent by the year 2000; 3) new plants will use cooling towers or ponds; 4) nuclear power production will increase from 17 percent in 1975 to 76 percent by 2000; and, 5) nuclear water use rates exceed fossil rates throughout the projection period.

The NAS power water use projections differ significantly from those in the MLP. In addition to different assumptions and water use coefficients, the NAS used data from the regional reliability councils that includes the entire Great Lakes region and their forecasts within the Great Lakes basin reflect power demand rather than power generation. Demand in the NAS projection will be satisfied by generation somewhere within the region. The critical difference is that this consumptive use study is concerned only with water use in the Great Lakes basin and water use in this sub-area of the Great Lakes region does not equate to energy demand.

Projections 4 and 5 are merely five percent and three percent annual power generation growth projections after the year 2000, based on the same basic data and assumptions that were used in the MLP.

Projection 6 incorporates all the assumptions used in the MLP except the one related to closed-cycle cooling. Instead, projection 6 is based on the assumption that power companies will be able to obtain variances from the Clear Water Act mandate concerning heated discharges. The law does allow variance on a case-by-case basis if lack of negative environmental impacts can be demonstrated. This alternative then incorporates in the MLP once-through cooling in the mix of thermal power plants that have not yet been built in addition to those presently using once-through cooling. Economics and siting are major factors that tend to preclude once-through as compared to closed-cycle cooling. The purpose of this scenario is not to recommend variance but rather is to demonstrate the magnitude of the impact of the Clean Water Act on water consumption in the Great Lakes basin as the law is currently applied.

6.8.2 Canadian Power Generation Water Use

Thermal power generation, the largest water withdrawal sector (Table 6-2) in the Canadian portion of the basin, is an extremely important facet of the Ontario economy. The total installed capacity of all power production plants in the province was 17,900 megawatts (MW) in 1975.

In 1975, thermal power production facilities totaled 11,500 MW of installed capacity; all of these facilities are located within the Great Lakes basin. Of the 11,500 MW of installed thermal power generating capacity, 77.6 percent is accounted for by conventional coal and oil-fired plants, 18.9 percent by nuclear plants and the remainder by other plant types such as gas turbine operations. The adopted forecasts are taken from several sources and tend to be on the conservative side of current predictions.

Principal assumptions underlying the MLP for thermal power generation are:

- the economic growth rate will remain constant over the entire projection period and will be equivalent to the growth rate generated by the CANDIDE projections (Annex F) of real domestic product for this industry;

- all thermal plants will employ once-through cooling systems;

- no substantial curtailments will be forced by environmental considerations; and,

- most stations in the future will be located on the Great Lakes.

Throughout this section, only the Ontario Hydro system is considered since minor industrial power producers were included in the manufacturing sector. Also, the forecasts assume that non-conventional sources (e.g. solar power) will contribute less than 10 percent of needs by 2035. Assistance was provided by Ontario Hydro in developing this methodology.

Forecasting water use for thermal power production must occur within the framework of overall power system planning. In this planning process, the emerging demands are quantified, the amount of power required to meet them is calculated, and the existing power network is expanded accordingly. Since the normal corporate planning process extends at most to 25 years in the future, official projections of energy demands, peak loads, etc., are available only to the year 2005. Also, firm planning for future facility location is available only to 1990. Thus the methodology adopted had to allow for the long projection period and the lack of a committed generation program past 1990. As in other sectors, a number of projections based on varying assumptions were constructed.

A forecast of peak power demands made by Ontario Hydro provided the starting point for the projections of water use. The agency allows an excess of dependable peak generating capacity over the peak demands of at least 25 percent. Thus for each five-year period beginning in 1975, the installed generation requirements could be calculated up to the year 2005. After 2005 the installed generating requirements were extended by extrapolation on the basis of four percent annual growth. This process provided an MLP of the capacity which will be required in the system.

With required capacities in place, the generating facilities were then broken into hydro-electric, fossil and nuclear types. For the years to 1990, Ontario Hydro has a committed expansion program, making it relatively simple to expand the current system. For 1990 to 2000, the agency has an unofficial and completely tentative program, which, despite its status, was used to estimate the MLP to 2000. Past that year, the demand for installed generating requirements over the capacity of the system for the high alternatives in 2000 was divided 65 percent nuclear and 35 percent fossil generating plants, with no expansion seen for the hydro-power system. For the medium and low alternatives this split was taken at 85 percent nuclear and 15 percent fossil.

With the broad outlines of the system in place, it was necessary then to determine the energy production from the hydro-electric, nuclear and fossil fuel plants. For a detailed description of the methodology used to determine energy production refer to Annex F. Once the actual energy production for each type of plant was calculated, water withdrawals and consumption were calculated using constant coefficients based on work in the GLBC Framework Study. For nuclear plants withdrawals average two cfs per megawatt (0.228 cfs/GWH), which translates to 45 million gallons per kilowatt-hour (KWH) of energy production. The corresponding figures for fossil-fueled plants are 1.2 cfs per megawatt (0.137 cfs/GWH) and 27 million gallons per KWH. For both types of plant, consumption is taken at 0.75 percent of withdrawals.

The location of future thermal stations is a complex function of several variables, among them the availability of water supplies, the proximity to markets and the location of transmission lines. Most stations in the future will be located adjacent to the Great Lakes, and for the period to 2000 there is some idea as to precise location. After 2000, however, the distribution of capacity was determined on the basis of past locations and the future distribution of population and industrial activity. After 2000, it is assumed that 95 percent of the installed capacity, and accordingly 95 percent of the water use, will be in the basin.

Peak demands on the Ontario Hydro system in 1975 totaled 14,535 MW. The total capacity (generated plus purchased) of the system was 18,657 MW, resulting in some overcapacity. This overcapacity results from an over-estimation of load growth. The overcapacity is expected to be reduced gradually and after 2000 installed generating capacity will be 25 percent in excess of peak demands. After 2000, the MLP annual growth rate in peak demands is projected at four percent. By 2035, there will be a peak demand of 143,600 MW, yielding a requirement for installed generating capacity of 179,500 MW. The expansions in peak demand and required installed generating capacity represent an average 4.57 percent annual growth rate over the entire time period.

The expansion program of Ontario Hydro, committed to 1990 and uncommitted to 2000, is built into the capacity figures. This expansion program displays a growing reliance on nuclear power, which will provide 51 percent of total installed generating capacity by 2000 and 61 percent by 2035.

With regard to power production, the system met a demand of about 81,900 GWH in 1975, broken down amongst the various plant types. By 2035, the total power demand is projected to be 1,069,200 GWH, a 4.4 percent rate of annual increase. The total power demand includes a net export of 3,000 GWH per year throughout the time period.

Water use for power based on the MLP is projected as follows:

MLP Projection

	1975	2035	Annual Growth Rate
Withdrawal (cfs)	6,600 (49%)	197,200 (79%)	5.8%
Consumption (cfs)	60 (8%)	1,540 (34%)	5.9%

The inherent shift in the MLP to nuclear power plants, a larger water user than fossil plants, causes the water use growth rate to be 1.2 percent per annum above the growth of power generating capacity.

The breakdown of total water use by lake basin was done by grouping existing and planned plants by basin and disaggregating total water use in line with the capacities of these plants. After 1990, when the precise location of plants is unknown, proportional distribution in the lake basins is assumed to remain constant.

In addition to the MLP, five projections were prepared (Figure 6-13); three deal with changes in the growth rate and two with technological variations.

The high, medium and low growth rate projections concentrate on the effects of varying the demands for power, and on consequent changes in production capacities. All these alternatives emphasize nuclear power as the dominant future means of power production. The high growth scenario uses an annual growth rate of five percent from 1980 to project peak power demands, while the medium and low growth scenarios use four percent and three percent growth rates, respectively.

The technological variations focus upon changes in the type of cooling system employed in Ontario thermal generating stations. The medium technology scenario employs cooling ponds on all capacity installed in the future, reusing this water so that the only water required is that to make up for evaporation and blowdown. The intensive technology scenario

Alternative Projections of Canadian Power Water Consumption

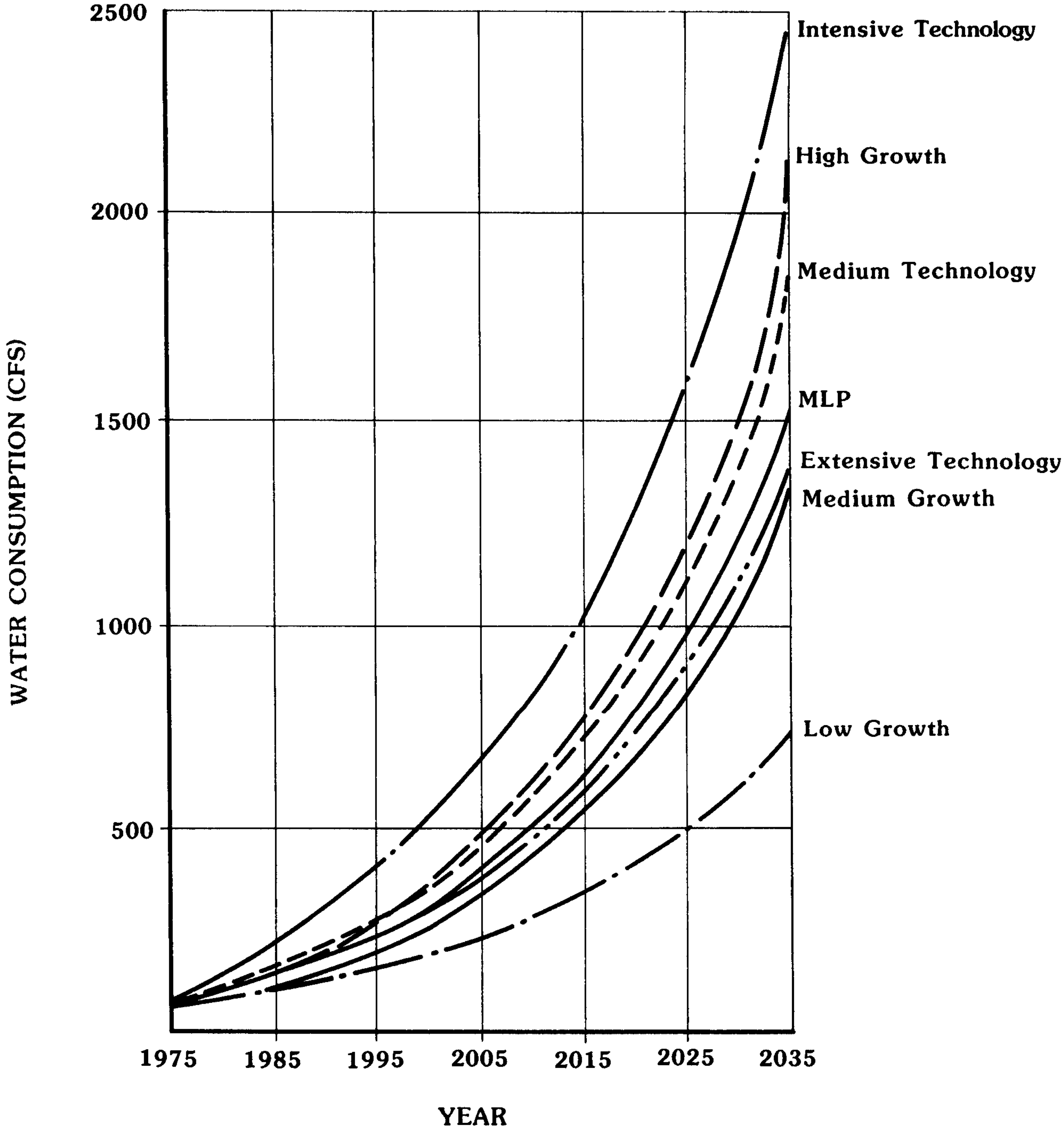


Figure 6-13

employs cooling towers instead of cooling ponds, but the make-up specifications are the same. It is also assumed that all current capacity and its replacement will retain a once-through cooling system. At the present time these two technology scenarios are seen as only remote possibilities. They are included here merely to show the effects on withdrawal and consumption if recirculating systems should be required in the future to limit environmental damages. In order not to include the effects of complex growth rates, MLP power projections are used for the medium and intensive technology scenarios.

The MLP is based on once-through cooling. With cooling ponds or cooling towers, the only new water required is to replace consumption, so water withdrawals increase very slowly over time giving the lowest water withdrawals. However, consumptive use is highest for the cooling tower option with an average annual increase of 6.8 percent as opposed to the MLP rate of increase of 5.9 percent.

6.8.3 Integration of U.S. and Canadian Data and Discussion

Power generation is the most significant withdrawal sector in the Great Lakes basin. Specific data based on the power sector MLP are shown below and in Table 6-3 and Figure 6-14.

	1975	2000	2035	Annual Growth Rate
Integrated MLP				
Withdrawal (cfs)	40,100 (53%)	89,500 (64%)	291,900 (75%)	3.4%
Consumption (cfs)	480 (10%)	2,600 (26%)	12,000 (47%)	5.6%
U.S. MLP				
Withdrawal (cfs)	33,500 (54%)	48,200 (59%)	94,700 (69%)	1.8%
Consumption (cfs)	420 (10%)	2,200 (27%)	10,500 (50%)	5.5%
Canadian MLP				
Withdrawal (cfs)	6,600 (49%)	41,300 (71%)	197,200 (79%)	5.8%
Consumption (cfs)	60 (8%)	310 (22%)	1,540 (34%)	5.9%

Commencing with a value of 33,500 cfs in 1975, the U.S. rate of withdrawals will increase prior to 2000 at a rate about one-half that after 2000 reflecting conformance with the goals of the Clean Water Act. After 2000, the withdrawals increase in proportion to mix of plants and cooling systems, to demand, to population growth and to economic growth rates to 94,700 cfs by the year 2035. Consumption, on the other hand, will increase through time from 420 cfs in 1975 to 10,500 cfs in 2035 representing an increase of 5.5 percent per annum.

Although Canada is much the smaller economic unit, it accounts for more than two times greater withdrawal by the end of the forecast period

Power Sector Consumptive Water Use Projections Total Great Lakes

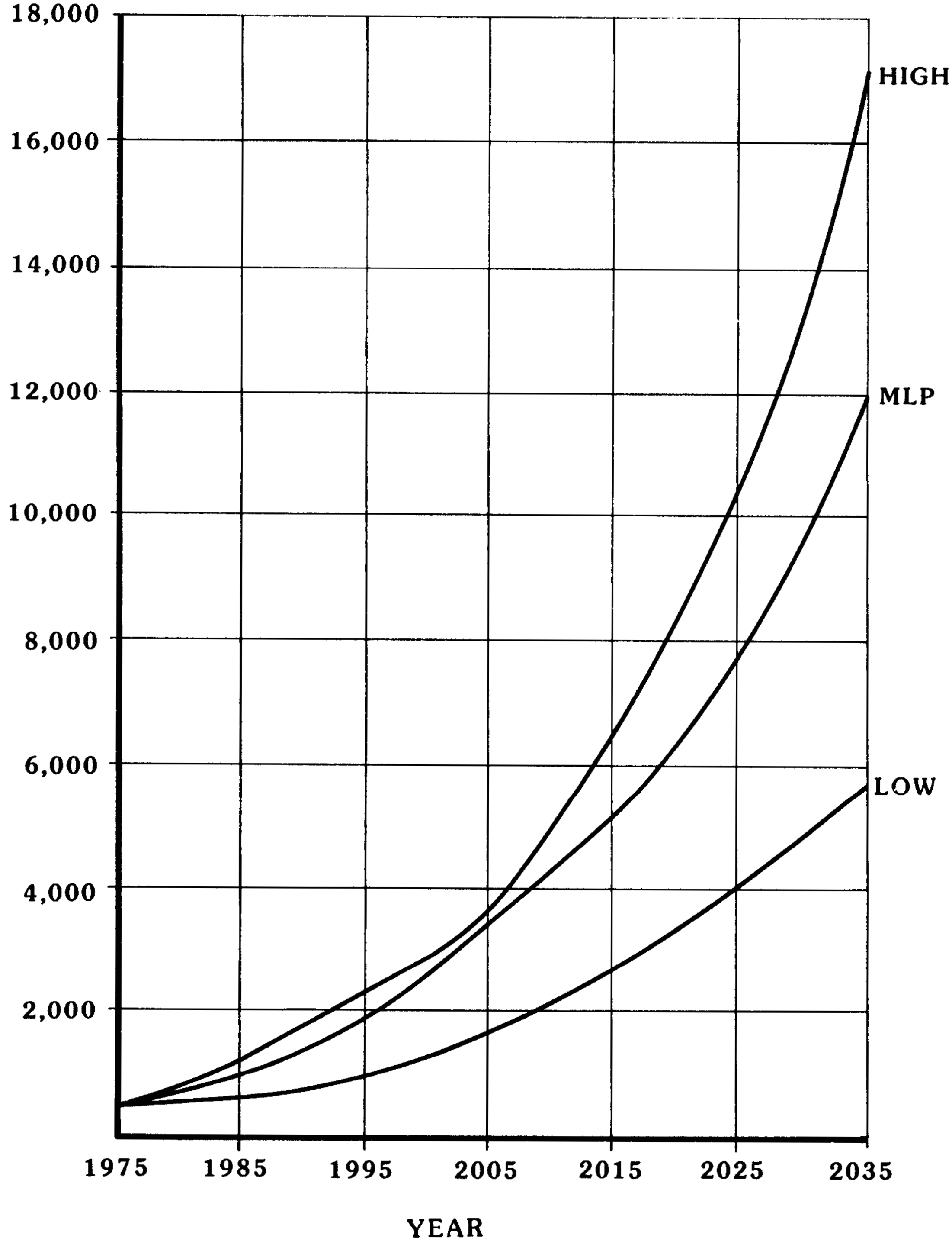


Figure 6-14

because of the assumed lack of environmental restrictions. The United States on the other hand, will be consuming about six to eight times as much water during the 60-year projection.

Forecasts for both the United States and Canada are based upon current information with regard to water use, prorated to 1975; both countries employ power production forecasts by their respective power agencies as the basis of the water use forecasts; and the general assumptions are consistent for both countries. The U.S. forecasts were done at a more disaggregated level and thus are probably more accurate. The forecasts differ in their approach to withdrawal and consumption rates; the rates are constant through the forecast period in Canada, but vary in the United States in keeping with the goals of the Clean Water Act.

6.9 Summary

Seven water use sectors were addressed in this study; they include Municipal, Rural-Domestic, Manufacturing, Mining, Stockwatering, Irrigation and Thermal Power Generation. Three of these, Rural-Domestic, Stockwatering and Irrigation are serviced exclusively by non-lake sources. This source difference would create a short term imbalance in the hydrologic cycle but all sources can be treated equally in the long term. From a continental perspective, agriculture is a major water user. However, this sector is a relatively minor user of Great Lakes waters because of the humidity and abundant precipitation in this temperate climatic zone.

6.9.1 United States

A major attraction of the Great Lakes region has been the abundant water supply and the manufacturing and power sectors have historically taken advantage of this attribute. In the United States, of the seven sectors that were investigated, the power industry withdrew the most water in 1975, 54 percent of the total, followed by manufacturing with 33 percent (Table 6-1). Municipal use was third at a nominal 10 percent. These three sectors accounted for 97 percent of total water withdrawals and are expected to account for the same percentage in 2035 although proportions will increase to 69 percent for power, reflecting its increasing dominance in the basin, and decrease to 20 percent for manufacturing and eight percent for municipal withdrawals, even though actual volumes will increase significantly in both of these sectors (Table 6-1).

As should be expected, growth rates will vary between sectors and sub-basin areas and will fluctuate in time, but the compound annual growth rate for total withdrawals is projected at 1.3 percent from 1975-2035. Total water withdrawals from the U.S. portion of the Great Lakes and their drainage basins are expected to increase 120 percent between 1975 and 2035 due to interacting effects of environmental controls and anticipated growth projections (Table 6-1), although the ratio of lake to non-lake withdrawals will stay at approximately 3:1.

Table 6-1 SUMMARY OF U. S. WATER USE FORECASTS (cfs)

Use Sector	Comp. Annual Growth Rate %	MLP % TOTAL USE 1975	MLP % TOTAL USE 2035	1975	1985 MLP	1985 High	1985 Low	2000 MLP	2000 High	2000 Low	2015 MLP	2015 High	2015 Low	2035 MLP	2035 High	2035 Low
Municipal																
Withdrawal	1.0	10	8	6100	6900	7300	6500	8100	8900	6900	9200	11100	7600	10800	14500	8700
Consumption	0.9	16	5	680	750	880	700	880	1200	750	1000	1600	840	1200	2200	970
Rural-Domestic																
Withdrawal	0.3	1	0	500	540	540	540	560	560	560	580	580	580	600	600	600
Consumption	0.3	7	2	300	330	330	330	330	330	330	350	350	350	370	370	370
Manufacturing																
Withdrawal	0.5	33	20	20400	21100	8600	24000	22900	5700	33000	24800	8000	43000	27600	10400	65000
Consumption	2.0	53	36	2300	2800	3300	2700	4000	5100	3500	5400	7000	4400	7500	9400	5400
Mining																
Withdrawal	1.3	2	2	1100	1300	1300	1300	1600	1600	1600	1900	1900	1900	2400	2400	2400
Consumption	1.1	6	2	240	270	270	270	330	330	330	380	380	380	460	460	460
Rural-Stock																
Withdrawal	0.1	0	0	130	130	130	130	130	130	130	140	140	140	140	140	140
Consumption	0.1	3	1	130	130	130	130	130	130	130	140	140	140	140	140	140
Irrigation																
Withdrawal	1.7	1	1	350	470	590	470	610	780	610	750	940	750	940	1180	940
Consumption	1.9	5	3	260	380	410	380	500	540	500	630	670	630	790	850	790
Power																
Withdrawal	1.8	54	69	33500	39900	39900	51800	48200	48200	103100	61000	70400	185700	94700	132400	406800
Consumption	5.5	10	50	420	830	830	650	2200	2200	1300	4500	5200	2300	10500	14600	5100
Total																
Withdrawal	1.3			62100	70400	58300	84700	82000	65900	145900	98500	93000	239600	137200	161700	484600
Consumption	2.7			4300	5500	6200	5200	8500	9900	6800	12500	15300	9100	20900	28000	13300

NOTES: 1) "High" and "Low" Forecasts refer to the Consumptive Water Use Cases.
2) Columns may not add due to rounding of sums.
3) Due to separate methods employed in the tabulation and rounding of data there may be negligible differences between forecast numbers in this Table and the corresponding numbers appearing in the DATA SET (Section 11 of Annex F).

Consumptive water use, that portion of water withdrawals that is not returned to the system, is expected to be five times greater in 2035 than it was in 1975 (Table 6-1). Consumptive use will increase from seven percent of total withdrawals in 1975 to 15 percent in 2035, or 20,900 cfs of the estimated 137,200 cfs that will be withdrawn. Manufacturing consumed 53 percent of the 4,300 cfs total in 1975 with municipal consumption at 16 percent and the power industry at 10 percent. These three sectors accounted for 80 percent of the water consumed in 1975 and will increase to 92 percent of the much larger volume of consumed water in 2035. An annual growth rate of 5.5 percent in consumptive use by the power industry is expected to be the highest. Existing legislation, environmental controls, economic considerations and institutional constraints account for the significant projected increases in consumption by the power and manufacturing sectors. In addition to the need to satisfy environmental concerns, these industries will tend to closed-cycle cooling to improve operational cost efficiency; this will reduce withdrawal rates but will account for the accelerated increase in consumptive water use.

The compounded annual growth rate in total water withdrawals is projected at 1.3 percent per annum and that for consumptive use is 2.7 percent (Table 6-1). Range of uncertainty is 1.9 to 3.2 percent for consumptive water use and, in an inverse relationship, 3.5 to 1.6 percent for water withdrawals.

These projections are based on the premise that the source of abundant water afforded by the Great Lakes will continue to be a major factor in the region. Even though a national water conservation policy is presently being espoused, the need will vary between regions. Because of this abundant fresh water supply, conservation will not be as stringent as in other parts of the United States and will be predicated by environmental and economic considerations. Additionally, the assumption is made that, despite short term trends of emigration of people and industries, the basic need for water will dictate continued growth in productivity and population in this region during the long term.

6.9.2 Canada

The total water withdrawal for the Canadian section of the Great Lakes basin in 1975 was 13,500 cfs, with consumption being 630 cfs, or 4.7 percent of withdrawals (Table 6-2). Withdrawals are dominated by thermal power which accounts for 49 percent of the total. The second largest water withdrawal use, manufacturing, accounted for 41 percent of the total or 5,600 cfs. These two uses together, therefore, account for 90 percent of total withdrawals. Manufacturing is the largest consumer of water in the basin at 220 cfs or about four percent of the corresponding water withdrawal. Consumption in thermal power generation, the largest withdrawal use, is only 0.75 percent of intake, making it the fifth largest consumer of water in the basin.

Table 6-2 SUMMARY OF CANADIAN WATER USE FORECASTS (cfs)

Use Sector	Comp. Annual Growth Rate %	MLP % TOTAL USE		1975	1985			2000			2015			2035		
		1975	2035		MLP	High	Low	MLP	High	Low	MLP	High	Low	MLP	High	Low
Municipal																
Withdrawal	1.6	7	1	930	1100	1300	900	1300	1600	1100	1700	2100	1400	2400	2900	1900
Consumption	1.5	22	8	150	170	200	140	200	240	160	260	310	210	360	430	280
Rural-Domestic																
Withdrawal	1.3	1	0	60	80	80	80	90	90	80	100	100	100	130	130	120
Consumption	1.7	7	2	30	50	50	50	60	60	50	60	60	60	80	80	70
Manufacturing																
Withdrawal	3.7	41	20	5600	8600	8800	7600	15100	16100	12000	25100	30600	18000	49400	72500	32000
Consumption	3.8	35	45	220	330	360	310	600	790	500	1000	1700	780	2000	4800	1500
Mining																
Withdrawal	3.8	1	0	130	200	220	190	370	450	310	610	930	520	1200	2500	1000
Consumption	3.9	0	1	0	10	10	10	10	10	10	20	30	10	40	70	30
Rural-Stock																
Withdrawal	1.7	1	0	80	100	120	80	120	150	100	160	200	130	220	270	170
Consumption	1.7	13	5	80	100	120	80	120	150	100	160	200	130	220	270	170
Irrigation																
Withdrawal	1.6	1	0	130	150	170	140	190	220	170	240	290	210	330	410	290
Consumption	1.5	15	5	90	110	120	100	130	160	120	170	200	150	240	300	210
Power																
Withdrawal	5.8	49	79	6600	18400	18600	14900	41300	44700	27500	80700	102400	47800	197200	285500	98700
Consumption	5.9	8	34	60	140	230	110	310	540	210	640	1100	360	1540	2500	740
Total																
Withdrawal	5.0			13500	28500	29300	23900	58500	63300	41300	108600	136600	68200	250900	364200	134100
Consumption	3.3			630	900	1100	800	1400	2000	1200	2300	3600	1700	4500	8500	3000

NOTES:
1) "High" and "Low" Forecasts refer to the Consumptive Water Use Cases.
2) Columns may not add due to rounding of sums.
3) Due to separate methods employed in the tabulation and rounding of data there may be negligible differences between forecast numbers in this Table and the corresponding numbers appearing in the <u>DATA SET</u> (Section 11 of Annex F).

By 2035, total withdrawals are projected to grow to 250,900 cfs, dominated to an even greater degree by power generation with 79 percent of the total. The compound growth rate for total withdrawals is five percent per annum as compared with a 5.8 percent growth rate for power withdrawals (Table 6-2). Manufacturing will continue to be the second largest withdrawal use at about 20 percent. Because of the way elements of the projections interact, with power accounting for only a very small proportion of consumption, the consumptive use will increase at only a 3.3 percent rate over the 60-year forecasting period to 4,500 cfs with thermal power generation and manufacturing together accounting for 79 percent of the projected total.

High and low scenarios show an expected range of growth for water use over the time period. The high scenario gives a growth rate of total withdrawal of 5.7 percent annually, with that for consumptive use at 4.4 percent. For the low scenario, these rates are 3.9 percent and 2.6 percent respectively. The direct relationship between water withdrawals and consumption reflects Canadian water use policy.

6.9.3 Great Lakes Basin

Combined U.S. and Canadian water consumption of 4,900 cfs in the Great Lakes basin in 1975 is expected to increase to 25,400 cfs by the year 2035. This increase of about 20,500 cfs is equivalent to 8.6 percent of the average discharge through the St. Lawrence River. The range of uncertainty is 16,300 to 36,500 cfs (Table 6-3, Figure 6-15) by the year 2035. The growth associated with this increased water use is expected to be focused in southern Lake Michigan, Lake Erie and western Lake Ontario. Over the 60-year period, 77 percent to 91 percent of all projected water consumption is attributed to three of the seven water use sectors, municipal, manufacturing and thermal power generation, although the relative significance of each of these major sectors will change with time. While varying considerably between water use sectors and sub-basin areas within the international Great Lakes, consumptive water use on a basin scale will remain a relatively constant 6.5 percent of water withdrawals (Table 6-3, Figure 6-16).

The quality of forecasts relates directly to the assumptions upon which they are based. The basic assumptions used in this study include population forecasts, changes in gross national product, industrial growth rates, changes in water use efficiencies, technological changes, trends in per capita consumption, extent of basin imports and exports and the significant one incorporated into the U.S. forecasts for manufacturing and thermal power generation: pollutant discharge goals as prescribed in the Clean Water Act. Uncertainty analysis is difficult in forecasts based on social and economic projections, but such analysis is absolutely imperative in attaching confidence to the numbers that are generated. The approach used here is based both on ranges of the input variables and incorporation of other relevant forcasts that have resulted in an envelope of forecasts that expands in time (Table 6-3, Figure 6-15). This technique demonstrates

Table 6-3 SUMMARY OF GREAT LAKES WATER USE FORECASTS (cfs)

Use Sector	Comp. Annual Growth Rate %	MLP % TOTAL USE 1975	MLP % TOTAL USE 2035	1975	1985 MLP	1985 High	1985 Low	2000 MLP	2000 High	2000 Low	2015 MLP	2015 High	2015 Low	2035 MLP	2035 High	2035 Low
Municipal																
Withdrawal	1.1	9	3	7000	8000	8600	7400	9400	10500	8000	10900	13200	9000	13200	17400	10600
Consumption	1.1	17	6	830	920	1100	840	1100	1400	910	1300	1900	1100	1600	2600	1300
Rural-Domestic																
Withdrawal	0.4	1	0	560	620	620	620	650	650	640	680	680	680	730	730	720
Consumption	0.5	7	2	330	380	380	380	390	390	380	410	410	410	450	450	440
Manufacturing																
Withdrawal	1.8	34	20	26000	29700	17400	31600	38000	21800	45000	49900	38600	61000	77000	82900	97000
Consumption	2.2	51	37	2500	3100	3700	3000	4600	5900	4000	6400	8700	5300	9500	14200	7000
Mining																
Withdrawal	1.8	2	1	1200	1500	1500	1500	2000	2100	1900	2500	2800	2400	3600	4900	3400
Consumption	1.2	5	2	240	280	280	280	340	340	340	400	410	390	500	530	490
Rural-Stock																
Withdrawal	0.9	0	0	210	230	250	210	250	280	230	300	340	270	360	410	310
Consumption	0.9	4	1	210	230	250	210	250	280	230	300	340	270	360	410	310
Irrigation																
Withdrawal	1.8	1	0	480	620	760	610	800	1000	780	990	1200	960	1300	1600	1200
Consumption	1.9	7	4	350	490	530	480	630	700	620	800	870	780	1000	1200	1000
Power																
Withdrawal	3.4	53	75	40100	58300	58500	66700	89500	92900	130600	141700	172800	233500	291900	418000	505500
Consumption	5.6	10	47	480	970	1100	760	2600	2700	1500	5100	6300	2700	12000	17100	5800
Total																
Withdrawal	2.8			75600	98900	87500	108600	140500	129200	187200	207100	229600	307800	388100	525900	618700
Consumption	2.8			4900	6400	7300	6000	9900	11900	8000	14800	18900	10800	25400	36500	16300

NOTES:
1) "High" and "Low" Forecasts refer to the Consumptive Water Use Cases.
2) Columns may not add due to rounding of sums.
3) Due to separate methods employed in the tabulation and rounding of data there may be negligible differences between forecast numbers in this Table and the corresponding numbers appearing in the DATA SET (Section 11 of Annex F).

Total Consumptive Water Use
Great Lakes Projections

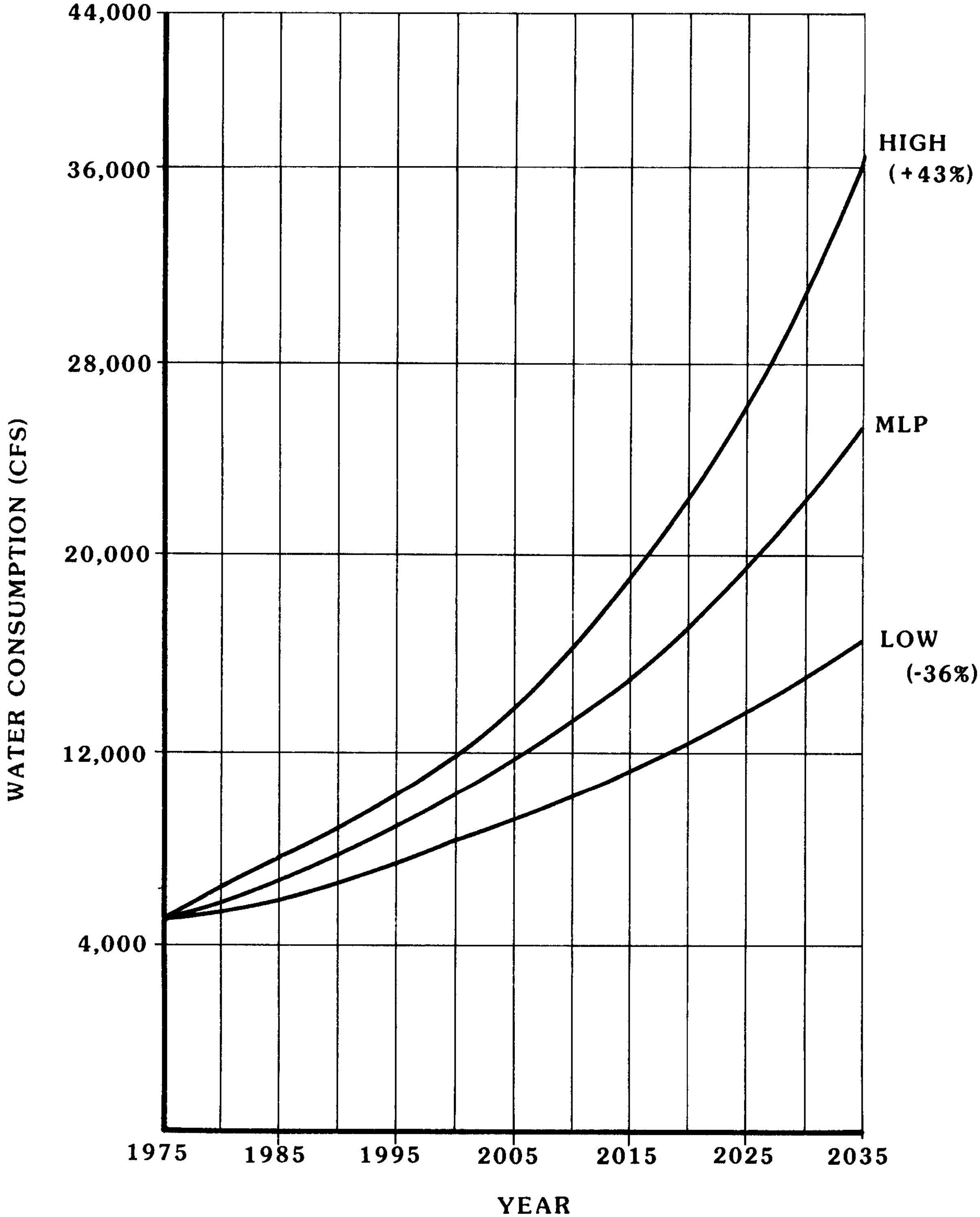
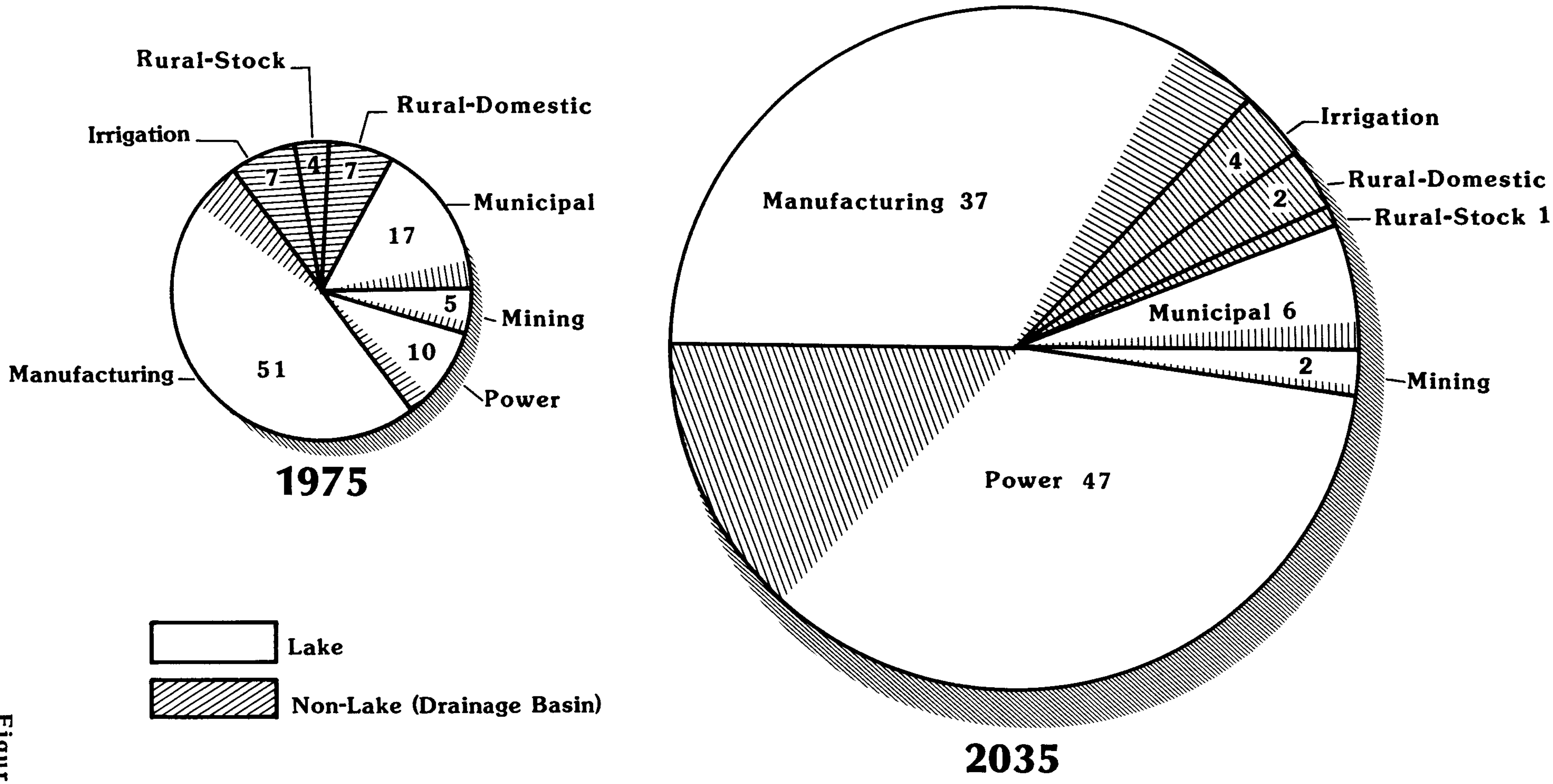


Figure 6-15

Relative Consumption by Water Use Sectors in the Great Lakes Basin 1975 and 2035



NOTE: Discrepancies are due to roundings

Figure 6-16

the uncertainties that exist in long-term socio-economic forecasts. Uncertainty by the year 2000 is ± 20 percent and by 2035 increases to an extremely tenuous ± 38 percent.

Economic analysis of the effect of increasing consumptive uses on Great Lakes levels and flows will determine the benefits and losses to power, navigation and riparian interests. However, presuming that a conflict may arise, consumptive use constitutes a transfer of water from one use to another use and the benefits of its availability must be balanced between the multiple conflicting needs and demands. This problem is extremely complex in long-term forecasts because economic and environmental benefits change rapidly in response to multiple short-term interactive events, rather than to long-term trends.

Consumptive water use projections which were generated in this analysis constitute an estimate of the water that society will demand from the Great Lakes during the next 60 years. This analysis was undertaken to quantify existing and potential consumptive water uses in order to determine the systemic impact of these steadily increasing future consumptive uses as one of the many hydrologic variables. The problem of potential inability of the supply to satisfy water demands has not been considered. However, the projected total consumptive use is a small percentage of the total flow through the lakes system so the possibility of general water shortages in the basin is remote.

This analysis provides a most likely projection based on anticipated demands that will continue to lower lake levels; it is not a plan to change them, such as could be accomplished through lake regulation, but such lowering is inevitable. It remains for the decision maker to evaluate the significance of projected water use and to apply these findings as appropriate to development of the most acceptable management strategy.

6.9.4 Comparison with International Great Lakes Levels Board Report

The International Great Lakes Levels Board (IGLLB) study contained a brief overview of consumptive water use. In fact, the current project was undertaken to expand the study of consumptive use, as new data and a shift in attitudes pertaining to Great Lakes water uses have occurred since the Levels Board report. A major development arising shortly after completion of the IGLLB study has been the implementation of management programs reflecting strong concerns about the environment and human health in the water and related resources fields. These massive programs focus primarily on the manufacturing and power sectors, two of the major water users in the Great Lakes basin. This section will compare IGLLB estimates of current and future consumptive use in the basin with the estimates developed in this study. The current MLP is used as the basis-of-comparison, although the ranges will also be useful in assessing the comparability of the IGLLB forecasts. The IGLLB study published estimates of water use for 1965, 1985, 2000 and 2030 so the comparison is based only on the last three dates. In the IGLLB report, the municipal and rural water uses and stockwatering sectors are combined under the Municipal-Rural heading, mining water use was not included in the Industry category, and agriculture did not include golf courses and public lands irrigation. These omissions are estimated to amount to 460, 570 and 800 cfs (consumptive use) in 1985, 2000 and 2030, respectively.

Total consumptive use projected to the year 2030 in the IGLLB report is 13,480 cfs (Table 6-4). In the four sectors identified in that study, differences between results range from 33 percent to 136 percent but the total is 61 percent of the 22,080 cfs that is currently projected to be consumed from the Great Lakes basin in the year 2030 or 65 percent after inclusion of comparable water uses.

The IGLLB projection approximates the lower boundary of the envelope of projections which were developed for the present study as could be expected in a projection made prior to implementation of environmental controls.

Table 6-4 COMPARISON OF WATER CONSUMPTION REPORTED IN THE IGLLB STUDY WITH THE PRESENT STUDY (cfs)

	Power		Agriculture		Industry		Municipal-Rural		Total	
	IGLLB	IDCUB	IGLLB	IDCUB	IGLLB	IDCUB	IGLLB	IDCUB	IGLLB	IDCUB
U.S.										
1965	150		100		560		1070		1880	
1985	340	830	120	380	1170	3060	1330	1210	2960	5480
2000	720	2720	150	500	2060	4360	1620	1340	4550	8460
2030	1860	8810	210	750	6390	7390	2440	1640	10900	18200
Canada										
1965	30		45		100		220		395	
1985	550	140	70	110	160	340	290	310	1070	900
2000	750	310	90	130	210	610	370	380	1420	1430
2030	1390	1320	170	220	390	1730	630	610	2580	3880
Total										
1965	180		145		660		1290		2275	
1985	890	970	190	490	1330	3400	1620	1520	4030	6380
2000	1470	3030	240	630	2270	4970	1990	1720	5970	9890
2030	3250	10130	380	970	6780	9120	3070	2250	13480	22080

IGLLB - International Great Lakes Levels Board

IDCUB - International Great Lakes Diversions and Consumptive Uses Study Board.

Section 7

DEVELOPMENT OF DIVERSION MANAGEMENT SCENARIOS

7.1 General

The word "Diversion" as employed herein means:

> "A transfer of water either into the Great Lakes watershed from an adjacent watershed, e.g., the Ogoki and Long Lac Diversions; from within the Great Lakes watershed into an adjacent watershed, e.g.; the Lake Michigan Diversion at Chicago; or from the watershed of one Great Lake into that of another; e.g., the Welland Canal. All such diversions are by means of channels controlled by man-made structures."

Traditionally, diversions into, within, and out of the system have been at a rate required to satisfy the needs for which they were established, with little consideration given to impacts on other users of the system. To address the Reference, the Board developed a computer model of the system which would:

(1) permit evaluation (hydrologically) of the current rates; and,

(2) permit evaluation (hydrologically) of possible variations in these rates; that is, the effect of diversions on lake levels and outflows had the diversions been at rates different than those specified under the "basis-of-comparison." The effect of varying diversion rates was evaluated over the full range of water supplies (precipitation and inflows) experienced during the period 1900-1976.

Documentation of the hydrologic model is contained in Appendix B entitled "Computer Models-Great Lakes." This appendix can be obtained in the United States from the Detroit District, Corps of Engineers and in Canada from the Inland Waters Directorate, Federal Department of the Environment, Ottawa, Ontario.

7.2 Development of Management Scenarios

In the development of alternative diversion management scenarios, the Board considered the needs of the users of the Great Lakes. Concern was primarily focused on the possibility of alleviating extreme high water levels.

However, consideration was also given to alleviating extreme low level conditions. In general the desire was to lower and reduce the frequency of high levels to benefit the "Coastal Zone" or shoreline interests, while maintaining as near as possible the mean and minimum levels to minimize the impact on the navigation and power interests. The development of the management scenarios proceeded in two phases:

(1) determination of maximum and minimum flow limits for each of the existing diversions, consistent with past experience and within present physical capacities; and,

(2) determination of an indicator to signal when a change in the diversion rate should occur.

7.2.1 Limits of Existing Diversions

The first phase of the investigation indicated the following:

a. Long Lac/Ogoki Diversions.

(1) It is physically possible to reduce the diversion of water from the Albany River watershed into the Lake Superior drainage basin to zero during periods of high water supply to the Great Lakes. In fact, as noted in Section 4, during the recorded history of these diversions the Ogoki Diversion has been completely closed.

(2) A review of the meteorological conditions of the Albany River watershed indicates that during periods of low water supply to the Great Lakes system the Albany River watershed experiences similar conditions; hence, it is not possible to increase the flow through this system during periods of low water supply on the Great Lakes.

For the purposes of this study, only a reduction in water supply to the Great Lakes system was considered. To bracket the various possibilities, two alternative reduction scenarios were selected for evaluation: a reduction in the basis-of-comparison rate of 5,000 cfs to 2,500 cfs and a complete reduction to zero.

b. Lake Michigan Diversion at Chicago. A review of the historic records of this diversion indicates that at one time an annual average of up to 10,000 cfs had been discharged through the system. Moreover, during periods of low local inflows the physical capacity of the system would permit maximum average daily discharges of approximately 12,000 cfs. However, computer modelling of the system indicates that this flow cannot be continually diverted, due to various natural phenomena and the necessity for constraining this release whenever bankfull or near bankfull conditions exist on the Illinois Waterway. Because of these constraints, the average annual diversion would approximate 8,700 cfs, with a monthly distribution as shown in Table 7-1. Based on this information and the desire to encompass the various possibilities, another two scenarios, in addition to the present 3,200 cfs, were selected for evaluation; i.e., increases to annual averages of 6,600 and 8,700 cfs.

Table 7-1
LAKE MICHIGAN DIVERSION AT CHICAGO
MONTHLY DISTRIBUTION OF MAXIMUM FLOWS
(IN CFS)

JAN	8,000
FEB	6,900
MAR	6,600
APR	5,700
MAY	5,800
JUN	7,600
JUL	8,600
AUG	11,800
SEP	11,800
OCT	10,400
NOV	10,700
DEC	10,200
AVERAGE	8,700

As in the case of the Long Lac/Ogoki Diversions, consideration was also given to decreasing the diversion during periods of low water supply to the Great Lakes system. However, as noted in Section 4, since this water is used for domestic and sanitary purposes, it is not practical to reduce this diversion from its present rate (3,200 cfs) by any substantial amount. In spite of the impracticality of a reduced diversion, the diversion's zero case was hydrologically evaluated (Section 8).

c. Welland Canal. During the period 1950 through 1976, the average annual rate of this diversion was about 7,600 cfs, with a maximum annual rate of 9,200 cfs (occurring in 1976). For the basis-of-comparison the value of 7,000 cfs was adopted as the average annual diversion. Study of the canal's operation showed that the maximum monthly discharge (with exceptions in 1976) was about 9,000 cfs, because of erosion and navigation problems caused by high current velocities. Hence 9,000 cfs was adopted as the maximum annual discharge. However, since 1976, increasing demands for water for power generation and navigation have caused the average annual diversion rate to exceed 9,000 cfs. To provide the needed water, the St. Lawrence Seaway Authority decided to release as much as 10,000 cfs during months of peak demand. Recognizing that 10,000 cfs cannot be discharged all the time due to disruptions to shipping and maintenance work, the figure of 9,400 cfs was determined to be the maximum average annual flow for the canal in the future.

Consideration was also given to reducing the flow during periods of low water. Recognizing that it is not practical to consider shutting off the diversion completely cutting off all navigation, dilution, municipal and industrial water supplies, the case of shutting down to 2,600 cfs (enough to maintain full navigation operation and water supplies) was adopted for a scenario which would be evaluated economically. However, the case of zero diversion has been evaluated hydrologically.

d. New York State Barge Canal System. As noted in Section 4, this diversion is from the Niagara River, with the water returned to Lake Ontario at various points. The New York State Barge Canal cannot be used for reducing Lake Erie levels, because its entry location is downstream of the natural hydraulic control section of the Niagara River. Therefore, no consideration was given to the use of this canal to modify the lake level regimes. Currently, the amount of water diverted through the canal averages about 700 cfs, with a maximum flow during the navigation season of 1,100 cfs.

7.2.2 Indicator for Changing Diversion Rates

The second phase of the investigation consisted of the development of an indicator which could be used to signal when a change in the diversion rate should occur. Two indicators were studied and evaluated as possible triggers: (1) lake level and (2) water supply. Figure 7-1 gives a comparison of these two indicators over the period 1960 to 1970. The upper curve shows the Lakes Michigan-Huron water level and the lower curve shows the net basin supply (NBS), i.e., the net water supply contributed to the lakes from their own basins. Both indicators have been plotted as 12-month moving means. Shown also is the long term (1900-1976) mean value for each. Various levels for turning the diversions on and off were studied; the mean value was selected. Water supply was found to be the better of the two indicators, because it permits an earlier change in diversion rates in a rising lake situation and an earlier return to the basis-of-comparison rates in a falling lake level situation. The diversion impact on maximum lake level conditions is thus maximized, while the impact on the mean and minimum lake levels is tempered. It is also indicated that the use of the water supply to Lakes Michigan-Huron, which is not only the major water supplier to the lower portion of the system, but also the basin that receives the greatest local supply, is a more responsive and timely indicator. The use of a 12-month moving mean permits a conservative response during a changing supply situation.

7.3 Diversion Scenarios

To cover the entire spectrum of possible variations in the diversion rates and to cover the information requested in the Reference to the Governments, the following diversion scenarios were developed.

7.3.1 Existing (1976) Diversion Scenarios

The Reference requested the Board to examine into and report upon the effect of the existing diversions within the system. To accomplish this portion of the study, four scenarios were developed, which remove these existing diversions (see Section 4) totally from consideration as a portion of water supply. The first three scenarios dealt with the diversions individually and involved the reduction of each of the diversions to zero from their programmed rate. The fourth scenario involved the reduction of all of the existing diversions to zero simultaneously. These scenarios, included in Figure 7-2, have been evaluated over the historic water supply period (1900-1976).

Comparison of Lake Level with Water Supply

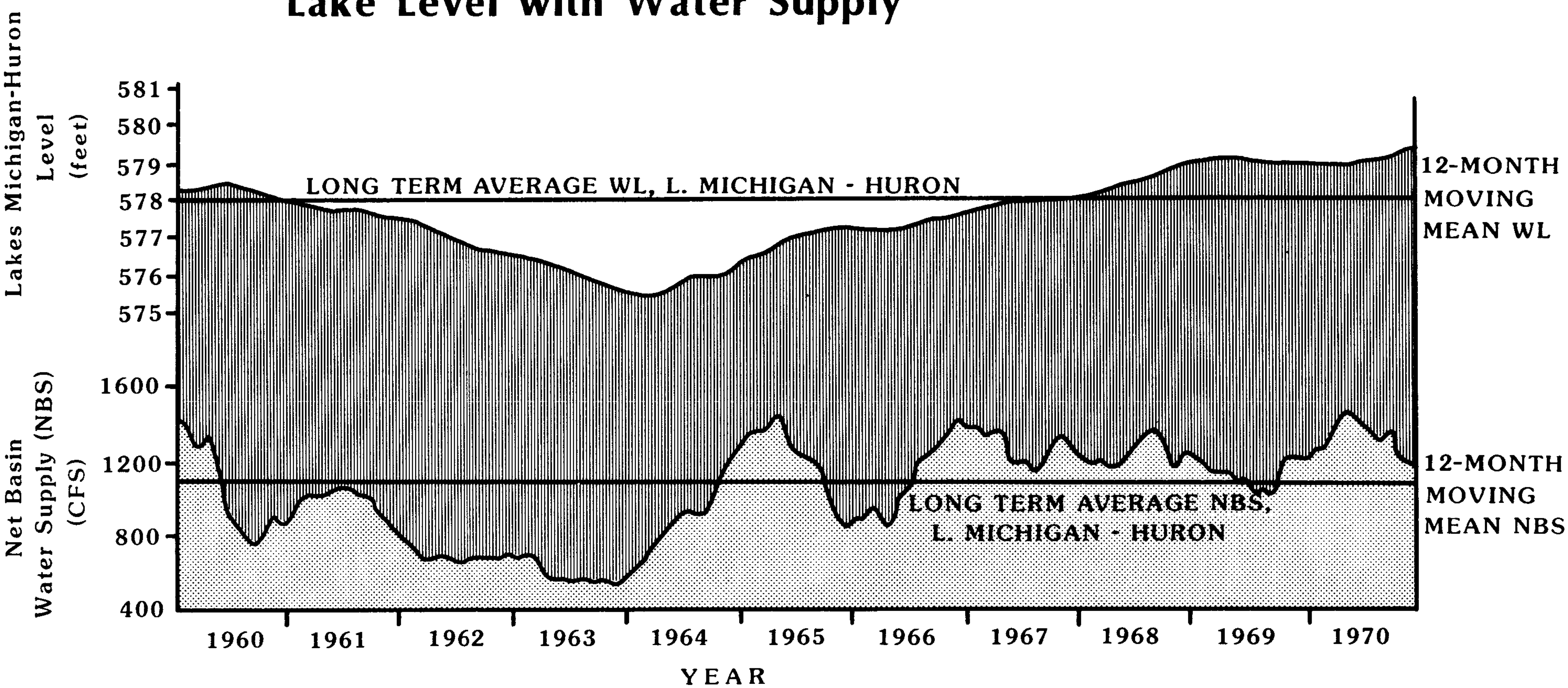


Figure 7-1

DIVERSION MANAGEMENT SCENARIOS CONSIDERED

LAKE MICHIGAN DIVERSION at CHICAGO WITH MICH-HURON AS TRIGGER -CFS- (columns, upper value) / **WELLAND CANAL WITH MICH-HURON AS TRIGGER -CFS-** (columns, lower value) / **LONG LAC/OGOKI DIVERSIONS WITH MICH-HURON AS TRIGGER -CFS-** (rows)

Long Lac/Ogoki	0 / 0	3200 / 0	6600 / 0	8700 / 0	3200 / 2600	0 / 7000	3200 / 7000	6600 / 7000	8700 / 7000	0 / 9000	3200 / 9000	6600 / 9000	8700 / 9000
5000	✓	✓	✓	✓	✓	✓	BASE CASE	✓	✓	✓	✓	✓	✓
2500	✓	✓	✓	✓	NA	✓	✓	✓	✓	✓	✓	✓	✓
0	✓	✓	✓	✓	NA	✓	✓	✓	✓	✓	✓	✓	✓

LAKE MICHIGAN DIVERSION at CHICAGO WITHOUT A TRIGGER -CFS- (columns, upper value) / **WELLAND CANAL WITHOUT A TRIGGER -CFS-** (columns, lower value) / **LONG LAC/OGOKI DIVERSIONS WITHOUT A TRIGGER -CFS-** (rows)

Long Lac/Ogoki	0 / 0	3200 / 0	0 / 7000	3200 / 7000	3200 / 9400
5600	NA	NA	NA	✓	✓
5000	NA	✓	✓	NA	✓
2500	NA	NA	NA	NA	NA
0	✓	NA	NA	✓	NA

LEGEND:

BASE CASE - *Basis-of-Comparison*

✓ - *Diversion management scenario considered (example, shaded combination: Long Lac/Ogoki at 2,500 cfs, Lake Michigan Diversion at Chicago at 6,600 cfs, and Welland Canal at zero)*

NA - *Not applicable*

Figure 7-2

7.3.2 Management Scenarios

In providing data to "assess the effects of varying the rates of the existing diversions, during periods of extreme levels on the Great Lakes," 36 diversion management scenarios were developed. They were chosen to encompass the full range of flows over which the diversion rates could be altered without change to the present physical capacities of the diversion facilities. The selected variations (see Figure 7-2) were studied singly and in various combinations. Each was evaluated over the historic water supply period (1900-1976); 35 scenarios altered the diversion rate whenever the water supply to Lakes Michigan-Huron was above normal; and one altered the rate whenever that supply was below normal (Long Lac/Ogoki - 5,000 cfs, Lake Michigan Diversion at Chicago - 3,200; and Welland Canal - 2,600 cfs). The latter case was developed to determine the impact of a reduction in Welland Canal flow to support low levels in the upper portion of the system. The levels and flows resulting from each of these tests, over the historic period, are presented in Annex G.

7.3.3 Sensitivity Scenarios

Section 5 documents the selection of the study period and the establishment of a basis-of-comparison. In the development of the basis-of-comparison early in the study, constant Long Lac/Ogoki and Welland Canal Diversion rates of 5,000 and 7,000 cfs, respectively, were employed. These flows which were also selected by the International Great Lakes Levels Board in carrying out its studies, are the approximate averages which existed over the recent historic period through 1976. However, a review of the diversions that have actually occurred to the end of 1979 has indicated that the Long Lac/Ogoki Diversions have averaged 5,600 cfs since their inception, and the present annual diversion down the Welland Canal averages about 9,200 cfs with a maximum rate of about 9,400 cfs expected in the near future. These increases in rates are due in part to the high water supplies that have generally existed throughout the region in the 1970s and the demand of certain management and contractual decisions which have been implemented. To evaluate the impact of these hydraulic changes, three additional scenarios were developed which reflect these changes. These scenarios are also shown in Figure 7-2 and have been evaluated over the 1900-1976 period.

Section 8

EVALUATION OF DIVERSION MANAGEMENT SCENARIOS AND CONSUMPTIVE USES PROJECTIONS

8.1 General

In its "Directive", the IJC requested the Board to examine and report upon the hydrologic, economic and environmental effects in relation to:

(a) domestic water supply and sanitation;
(b) navigation;
(c) water supply for power generation and industrial purposes;
(d) agriculture;
(e) shore property, both public and private;
(f) flood control;
(g) fish and wildlife, and other environmental aspects;
(h) public recreation; and,
(i) such other matters as the Commission may indicate to the Board during the course of the study.

In responding to the "Directive" the Board developed techniques which would broadly encompass the impacts on the above interests. Outlined in the following sections is a brief summary of the approach employed in this study and in the evaluations of selected diversion management scenarios and the hydrologic evaluation of consumptive use projections.

8.2 Hydrologic Methodology

The two primary hydrologic factors to be evaluated are lake levels and outflows. Analysis of these factors includes consideration of the maximum, mean and minimum monthly values, and range, duration and seasonal distribution. Various hydrologic criteria were developed for evaluation purposes. The evaluation involves the determination of the degree to which the diversion management scenarios and the consumptive use projections meet these hydrologic criteria. This involves a comparison between the changed regime and the basis-of-comparison data.

8.3 Economic Methodology

The major economic interests affected by variations in levels of the Great Lakes fall into four general groups: (1) coastal zone, (2) beaches and boating, (3) hydro-electric power, and (4) navigation. The techniques for evaluation of economic impacts on these interests were developed by the International Lake Erie Regulation Study Board for use in both this study and its own study.

In evaluating the effects on these interests, available information and technical data were used as much as possible. Since any evaluation is dependent on the accuracy of the input data, an examination of the basic data was conducted. Data deficiencies and limitations were identified. Where no data existed, as in the case of recreational beach and boating facilities, surveys were conducted in selected parts of the system for collecting the necessary data.

Additionally, in order to determine the impact on the economic results caused by variations in the major assumptions, sensitivity analyses were conducted. These analyses are presented in detail in the appendices of the International Lake Erie Regulation Study Board (ILERSB) and are described briefly below.

8.3.1 Coastal Zone

Properties within the coastal zone are subject to two basic types of damage; inundation (flooding) and erosion. Inundation damages vary with the stormwater level, this being the stillwater level plus the superimposed wind-generated stormwater (temporary) rise at a specific location. Erosion was assumed to vary directly with the intensity of wave energy reaching the toe of the shoreline bluff.

8.3.1.1 Inundation

The methodology used to evaluate inundation differs from previous studies in that ultimate water levels (stillwater plus stormwater setup) were used as an index of inundation damages. For the United States coastal zone, damage data were based on the survey of the four year period from Labor Day, 1972, to Labor Day, 1976. Damage data for the Canadian portion of the Great Lakes were based on the Canada-Ontario Great Lakes Shore Damage Survey, covering the period November 1972 to November 1973. For the Quebec portion of the St. Lawrence River, 1974 and 1976 inundation events were used as the basis for inundation damage data. Monies spent on construction of new protective works to prevent or alleviate inundation damages were not included in the damage data utilized.

Stormwater stage-damage curves were developed and calibrated based on the recorded stormwater levels of the survey periods and known damages. In developing a relationship between stormwater levels and damages, it was assumed that the stillwater level and storm setup, acting independently or in combination, are capable of producing damage to the coastal zone. In other words, even at below average lake levels, severe storms can cause inundation damages. At above average lake levels, a small storm can also damage the coastal zone. Damages in any one month may be caused not only by a once-a-month stormwater level, but also by other lower levels during the month. Thus, the stormwater levels are only an index of damage potential. Estimated inundation damages were derived for each month of the year and summed to obtain an annual damage. Average annual damages were based on the annual damages over a period of time.

In evaluating the Quebec portion of the St. Lawrence River, it was necessary to take into account the effects of local inflow and Ottawa River inflow to the Montreal region. The outflow from Lake Ontario, the local inflow, and the Ottawa River flow were assumed to be independent of one another. Average annual damages were based on the combined probability of these events.

8.3.1.2 Erosion

The methodology used to evaluate erosion damages utilizes a "wave energy" technique in the development of stage-damage curves. Wave energy is considered to be the main factor in causing damage to structures and loss of land through erosion. Using the wave climate, mean beach slope and the elevation of the bluff toe above a reference level, an index of damage was determined. This index, computed on each reach for each month, was used to convert stage-energy curves to stage-damage curves.

For the United States, the erosion damages utilized were based on the same damage survey as the inundation damages. For the Canadian portion of the Great Lakes, potential future damages were based upon historic erosion rates and shore property values.

Since there would be a decrease in the frequency of occurrence of high flows in the St. Lawrence River, (to a varying degree under all conditions evaluated herein), there would be a decrease in erosion damages. This would somewhat increase the overall benefits to the coastal zone interests. However, there were insufficient data to quantitatively evaluate the impact of this reduction in damages.

There are several major factors which influence the coastal zone evaluation. These factors include shoreline development, increasing value of already developed coastal zone properties and assumed wear-off rate. In this study, it was assumed that there would be no future development of presently undeveloped land, due to the institution of shoreland management in Canada and the United States. Also, it was assumed that there would be no increase in the value of already developed coastal zone properties. The benefits, accruing as a result of a reduction in erosion due to lowered mean lake levels, were assumed to completely wear off after 50 years. This is because erodible shorelines will, over a period of time, adjust to a change in mean water level. Within this period, shoreline activities are expected to come into equilibrium with changing mean water levels, resulting in a reduction and eventual elimination of the effects of these changes.

Different assumptions were made in assessing the sensitivity of these factors. Under this sensitivity analysis, it is assumed that shoreline development and property values in the U.S. coastal zone will increase, and therefore these factors were taken into consideration. However, they were not considered for the Canadian coastal zone, because existing shoreline management policies are expected to be effective in preventing development.

Sensitivity analyses conducted for inundation and for erosion are included in Appendix "C" to the International Lake Erie Regulation Study Board report, 1981.(13)

8.3.1.3 Water Intakes

Many communities and industries along the shoreline of the Great Lakes and their connecting channels have lake water intakes. A survey of these intakes was carried out in the International Great Lakes Levels Board Study. The methodology used by the Levels Board to determine impacts of changing water levels on intakes was adopted for this study. The methodology compares pumping costs for water levels under the basis-of-comparison conditions with those under the diversion scenarios presented herein. The difference in pumping costs between the two conditions represents a benefit or loss.

8.3.1.4 Marine Structures

The analysis of effects of diversion management on coastal marine facilities was based on techniques developed by the International Great Lakes Levels Board, 1973.(9) In reconsidering the data and techniques used in the IGLLB study, it was determined that dry-rot of timber sub-structures is no longer a major problem; hence, it was not considered in this evaluation. The methodology used to evaluate marine structures associated with recreational boating is addressed in the following paragraphs.

8.3.2 Recreational Beaches and Boating

8.3.2.1 Recreational Beaches

The methodology is based on the premise that altered lake levels will generate changes in beach area. These changes are then related to their ability to provide recreational opportunities. By assigning a dollar value to the recreational opportunities, benefits or losses were quantified. This was accomplished by comparing the lake levels under the scenarios to that which occurred under the basis-of-comparison.

The following assumptions were used:

1. only beaches accessible to the general public were included;

2. the total number of beaches would remain constant throughout the study period;

3. expansion of public beach area through acquisition and development would not occur; and,

4. swimming is the indicator activity for beach use.

The economic impacts were determined in the following manner:

1. Determine the change in swimming opportunities due to changes in the lake levels. This was based on the present and future use of swimming opportunities.

2. Calculate the monetary value of an opportunity.

In determining benefits, it is necessary to establish when additional opportunities would actually be used. Benefits occur when beach use under a given scenario exceeds the number of opportunities available under the basis-of-comparison conditions. However, if a beach area is larger, due to changes in lake levels, but the additional opportunities are not actually utilized, there would be no benefit.

Inputs to the Canadian model were based on the Ontario Recreation Survey (collected in 1974-78) for natural environment swimming. In the United States, where no survey data were available, an allocation model was developed. Future beach use was determined by a straight-line function of population growth in the origin zones over the 50-year evaluation period. The value of an additional opportunity realized by the recreationist is based on the following:

1. the function of distance traveled, and a weighted entrance fee for each destination zone;

2. the dollar value for the average distance traveled, based on the cost per mile of driving a private automobile; and,

3. entrance fees.

Actual field data and beach assessment calculations are presented in Appendix G, Recreational Beaches and Boating, of the International Lake Erie Regulation Study Board report, 1981.[13]

8.3.2.2 Recreational Boating - U.S. Data Only*

Changes in water levels affect recreational boating activity. The impacts measured in this study are effects on recreational boating resulting from owners being prevented safe ingress/egress from the boat slips or prevented from mooring their boats, due to insufficient depths. Though it was recognized that damages to boating activities may result from water levels too high for boat owners to safely use their crafts (e.g., inundated docks), this analysis considered only the effects of low water level damages. Furthermore, this analysis considered only the effects of water level fluctuations on recreational boating for activities originating at commercial facilities (e.g., marinas). Boats berthed at private residences, summer cottages, etc. were not considered.

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*A similar study on Canadian recreational boating was not undertaken, due to lack of sufficient readily available data and lack of funds to collect information.

Impacts on recreational boating, resulting from changes in lake levels, were calculated as benefits or losses resulting from the difference between a particular scenario and the basis-of-comparison condition.

The method employed to calculate benefits and losses on recreational boating is explained in detail in three separate sections of Appendix G of the Lake Erie Board report: Stage-Damage Relationship, Stage-Duration Relationship, and Average Annual Damage Computations. The stage-damage relationship is the measurement of the effects of various water levels on boating use. If a given water level provides an average depth of four feet at each berth at a particular harbour, then it is assumed that any boat which has a draft of four feet or more would be unable to safely leave or enter its berth. The basis for calculating this impact in monetary terms is obtained from the "small-boat formula" derived by the U.S. Army Corps of Engineers ("Survey Investigations and Reports--Benefit Evaluating and Cost-Sharing for Small-Boat Harbor Projects," EM 1120-2-113, June 11, 1959.) The "small-boat formula" can be summarized as follows: "Boat owners are assumed to receive non-monetary returns in the form of boating enjoyment that would be equivalent to the rate of return on investments of comparable size in the 'for hire' boating sector and the absence of impediments to boating." The investment upon which the calculations were made is based on the depreciated value of the fleet, which is taken to be equal to 50 percent of the purchase price, where:

1. average age of a boat in the fleet is n/2 (n=life of the asset); and,

2. straight-line depreciation is used.

These calculations were carried out for all classes of boats based at the marina facilities.

The stage-duration concept is a measure that relates the probability of a water level being equalled or exceeded during a certain period of time. A stage-duration curve was developed for each of the scenarios and for the basis-of-comparison for each reach in the study area. Each stage-duration relationship was derived from May through September water level data for the period 1900-1976. It was assumed that the period May through September, inclusive, represents the recreational boating season throughout the study area. Though recreational boating occurs as early as April and as late as October, many studies indicate that recreational boating in these two months (April and October) accounts for a very minor portion of total boating activities.

The average annual damage computation represents the integration of the stage-damage and stage-duration relationships. This computation measures the damage that would be expected to occur in any one year. Average annual damage was computed using associated stage-duration relationships for each of the proposed scenarios and for the basis-of-comparison.

The benefits or losses associated with each scenario were computed by taking differences between average annual damages under each scenario and the basis-of-comparison.

Details concerning method, data and calculation are provided in Appendix G of the International Lake Erie Regulation Study Board report.

Although the boating evaluation involved determining the impacts on recreational boating activity, existing boating facilities and commercial fishing activities, the ramifications of the curtailment of sports fishing participation were not a considered factor. The total economic value of sport fishing was estimated in a 1979 status report of the Great Lakes Fishery Commission at one billion dollars annually.[18] This figure is based on the amount of money people are willing to spend for such items as food, bait, motels, boats, and special gear and clothing. Recreational anglers directly spend about 440 million dollars to fish the Great Lakes. This translates into approximately one billion dollars in regional incomes as contrasted to the 160 million dollar impact of commercial fishing as estimated by the Great Lakes Fishery Commission.

8.3.3 Power

The effects of changes in lake levels and flows on hydropower generation were determined by comparing the power that could be generated under the basis-of-comparison with the power that could be generated under each of the various scenarios and evaluating the difference in terms of the cost of replacement power.

The existing hydro-electric installations on the outlet rivers of the Great Lakes that could be affected by changes in the water level and flow regime of the system have a total installed capacity of just over 8,000,000 kw. It was assumed that there would be no change in this installed capacity over the 50-year study period 1985 through 2035.

8.3.3.1 Determination of Power Generation

Power generation in terms of peak load meeting capability, and energy outputs from power installations on the Great Lakes depends on the net head and flows available. The methodology for determining the peak and energy output is explained in detail in Appendix F of the International Lake Erie Regulation Study Board report, 1981.[13] Computer models that had been developed for each plant or group of plants were up-dated as required.

The model input is the 77-year regime of monthly mean lake levels and outflows, as developed for the basis-of-comparison and for each scenario. For each month of the study period 1900 through 1976, the computer programs determine the amount of water available to each plant, except the U.S. Niagara plants, the corresponding head, the average monthly energy output, and the peak output. The average annual energy and peak load meeting capability were calculated from the above computer outputs.

In the case of the U.S. Niagara plants, the gain or loss in energy and peak output were derived from an analysis of duration listings of monthly Lake Erie outflows.

On the St. Marys River, the power output from the Canadian plant is based on the redeveloped Great Lakes Power Corporation Plant, which will be operational in 1982. The methodology was developed by Ontario Hydro in co-operation with Great Lakes Power Corporation Limited and its consultant.

Ice conditions limit the flow at the time that the Hydro Quebec system experiences peak load; therefore, no peak capacity benefits are expected on this system.

8.3.3.2 Determination of Benefits or Losses

The average annual energy and load meeting capability for each plant or group of plants as determined for the basis-of-comparison were subtracted from the corresponding values for each scenario being evaluated to determine the benefit or loss. Although this methodology may appear to be obvious, it is mentioned to clarify the fact that the economic evaluation was based on the gain or loss in power and not on the total generation.

8.3.3.3 Determination of Unit Costs

To evaluate the various scenarios, the annual value of replacement energy and peak capacity over the study period were estimated. These cost estimates assumed a discount rate of 8.5 percent, a project economic life of 50 years (1985 to 2035) and July 1979 price levels.

In the case of Ontario Hydro and Hydro Quebec the system values included inflation. These were first converted to 1979 dollars by a deflation factor.

The Ontario system values are based on replacement power generation from an anticipated mixture of coal and nuclear. The Quebec values are based upon hydro-electric replacement to 1995 and nuclear thereafter. The New York State values are calculated using oil as the replacement fuel and assuming a five percent price increase compounded annually from 1979 through 2005, and no further increase thereafter. For the upper Michigan plants on the St. Marys River, the present costs were assumed to occur throughout the 50-year study period.

For each system the 50 years of annual costs in real 1979 dollars were discounted at 8.5 percent to 1985 values to arrive at the total present worth. The annual amortized value was determined from the total present worth by dividing by 11.5656 (the sum of the present worth factors). The annual amortized replacement costs of energy and capacity for each system are shown in the following table:

Table 8-1
AVERAGE ANNUAL COST OF
REPLACEMENT POWER 1985-2035
IN 1979 DOLLARS

System	Quebec	Ontario		New York	U.S. Plants Upper Michigan
		Day	Night		
Energy Mills/KWH	7.568	17.24	12.12	110.6	3.36
Capacity $/KW		33.08		70.0	28.33

8.3.4 Navigation

The economic effect on commercial navigation due to a diversion scenario was computed as the difference between the annual costs of transporting lake cargo under the basis-of-comparison and scenario lake level regimes. Dredging to re-establish water depths (in the channels and harbors) reduced by diversion management, is an option which can be used to avoid the loss of load-carrying capacity. The cost of this alternative has been estimated in this study. The technique for this evaluation is outlined briefly below. For a detailed description of the technique, see Appendix D of the International Lake Erie Regulation Study Board report, 1981.(13)

8.3.4.1 Transportation Cost

The relationship between lake levels and transportation cost is based on the allowable draft of shipping. In the Great Lakes - St. Lawrence River system, the allowable draft is limited by the depth of water in the harbours and the connecting channels between the lakes. When the depth in one of these "restricted" parts of the system is altered by a change in lake levels, the allowable draft, and therefore the loading of ships wishing to use that part of the system at that time, may be affected. Any change in the loading capacity of ships, on a given route, would result in a change in the number of ship-hours required to move a given volume of goods over that route. A change in the number of ship-hours required would change the total operating expenses involved, and therefore change the total cost of transporting those goods.

This reasoning forms the basis of the evaluation methodology applied monthly to each shipping route in the future Great Lakes - St. Lawrence River trades. Annual total transportation costs for the entire system were calculated for each scenario. These were compared with the transportation cost for the basis-of-comparison case. The difference in costs between the basis-of-comparison and the scenario is the benefit or loss to shipping.

The methodology is composed primarily of forecasts of commodity traffic, vessel fleets and operating methods for the navigation system.

Unpredictable political considerations can affect the operation of the system. These include wars, major depressions and government transportation policies. These are discussed in Appendix D to the International Lake Erie Regulation Study Board report.

8.3.4.2 Dredging

Navigation losses could be eliminated if harbours and connecting channels were dredged to offset any decreases in mean lake level caused by regulation. If the relationship between mean lake level and the low water datum that existed prior to altering the levels regime is maintained by dredging, then losses in tonnage carried and transportation revenue would not occur. The cost of dredging United States Federal harbours and channels to depths of 1/4, 1/2 and 1 foot was determined and curves of depth versus cost plotted for each lake and connecting channel. It is not possible to dredge to tolerances of 1/4 or 1/2 foot; however, it is considered likely that such dredging could be accomplished by modifying the regular maintenance dredging contracts to pay for the additional depth desired.

A similar estimate of dredging requirements and costs for Canadian harbours was not undertaken due to a lack of sufficient readily available data.

Based on the International Lake Erie Regulation Study Board analysis, the costs of dredging U.S. harbours and channels to compensate for the lowering of the levels by Lake Erie regulation would be greater than the losses to the U.S. fleet. Therefore, it was concluded that dredging would not be a viable alternative for eliminating navigation losses, in the case of Lake Erie regulation.

Analysis of Scenarios 1, 6, and 7 (see Section 8.5) shows that for Scenario 6 dredging costs would be greater than navigation losses, but less than navigation losses for Scenarios 1 and 7, as shown in the following table.

Scenario	Cost of Dredging to Restore Water Depths (U.S.)	Navigation Losses Caused By Reduced Depths (U.S.)
1	$85 million	$131.5 million
6	$7.4 million	$ 4.5 million
7	$40 million	$ 45.2 million

The reasons for this are as follows:

1. Scenario 1 would reduce to zero the Long Lac/Ogoki Diversions into Lake Superior. This would affect the levels on all lakes by about 0.2 to 0.3 foot. Since Lake Superior is the predominant controlling lake (followed by Lakes Michigan-Huron), the navigation losses would be considerably higher than the cost of dredging.

2. Scenario 6 would increase the flow out of Lake Erie through the Welland Canal. Therefore, the greatest effect would be on Lake Erie levels where the mean would be lowered by about 0.05 foot. As expected, the dredging cost would be greater than the navigation loss because the depth in Lake Erie is not often the controlling factor in inter-lake shipping.

3. Scenario 7 would increase the Lake Michigan Diversion at Chicago. Therefore, the greatest effect would be on Lakes Michigan-Huron levels. In this case, navigation losses would be greater than the dredging costs because a loss of depth in this lake affects a substantial portion of U.S. shipping.

Therefore, dredging would be a viable alternate for eliminating U.S. navigation losses that would be produced by Scenarios 1 and 7.

8.4 Environmental Methodology

Although limited in detail, the environmental evaluation for this study covers the subjects of fisheries, wildlife/wetland and water quality.

8.4.1 Fisheries

Although diversion-induced lake level changes are small when compared to natural fluctuations, fish may be affected through alterations in nearshore habitat, reductions in hypolimnion volume or changes in seasonal water level fluctuations. These potential effects were addressed using the published literature and a general knowledge of fishery biology. In addition, published correlations between water levels and the success of fish stocks in the Great Lakes are employed. Three water level conditions resulting from the maximum-effect diversion scenario were evaluated in relation to impact on the fishery: the long-term monthly mean level; the monthly mean levels during a period of high levels; and, the monthly mean levels during a period of low levels. A four-year period of high or low water levels was examined, since this period would be of sufficient duration to sustain the establishment of vegetation and aquatic organisms and their habitation by fish life.

8.4.2 Wildlife/Wetlands

The probable effects of the various diversion scenarios on wildlife were evaluated through the analysis of impacts that changes in water levels would have on the wetlands. The importance of each type of wetland to wildlife was established from the available literature, including information on species life-cycle preference for different wetland types.

The existing Great Lakes wetlands have evolved in response to historic water level fluctuations and environmental changes. Seven wetland types were defined based on physical characteristics, and the response of these types to water level changes was evaluated. Wetlands were considered to consist of four major vegetative zones which shift position or change in size with alterations in long-term water levels. Graphs were developed which indicate the percentage of total wetland area occupied by these four zones at any water level for two specific wetlands. These graphs were used in conjunction with long-term water level alterations as the basis for evaluating corresponding changes in wetland composition under the various diversion scenarios. The changes in wetlands were then analyzed in terms of potential effects on wildlife.

8.4.3 Water Quality

Since the lake level changes associated with the various scenarios are rather small, it appears that any changes in the open lake water quality would be minimal. However, the diversions and consumptive uses scenarios could produce substantial changes in nearshore water depths and consequently cause substantial changes in nearshore water quality. Furthermore, since most water uses occur in the nearshore areas, any changes in the quality of nearshore water would be generally more noticeable than changes in mid-lake. In light of the above, and since the nearshore is the most important lake area for wildlife, fish production and various human activities, the water quality study places emphasis on these areas.

Water quality characteristics examined include hypolimnion volume and oxygen resources, general lake water quality, phosphorus and turbidity concentrations, Cladophora production, embayment water quality and waste dispersion capability. All characteristics were assessed through the use of appropriate existing models or modifications, except for the Cladophora assessment which is based on Cladophora production being a function of substrate and lake bottom topography. In most instances a quantification of the water quality changes resulting from the maximum-effect diversion scenario was made.

8.5 Evaluation of Selected Diversion Scenarios

To address the issues raised in the "Reference," the Board selected, from the total array of scenarios evaluated (Figure 7-2), the following scenarios for detailed hydrologic review. In selected cases, as noted by an asterisk, detailed economic review was made.

(a) Four scenarios which show the impact of the existing diversions:

	Diversion	Rate (cfs)
*Scenario 1 -	Long Lac/Ogoki	0
	Lake Michigan at Chicago	3,200
	Welland Canal	7,000
Scenario 2 -	Long Lac/Ogoki	5,000
	Lake Michigan at Chicago	3,200
	Welland Canal	0

*Scenarios selected for detailed economic review.

Scenario 3 -	Long Lac/Ogoki	5,000
	Lake Michigan at Chicago	0
	Welland Canal	7,000
Scenario 4 -	Long Lac/Ogoki	0
	Lake Michigan at Chicago	0
	Welland Canal	0

(b) Five scenarios which alter diversion rates whenever the water supply to the upper Great Lakes is above normal:

	Diversion	Rate (cfs)
*Scenario 5 -	Long Lac/Ogoki	0
	Lake Michigan at Chicago	3,200
	Welland Canal	7,000
*Scenario 6 -	Long Lac/Ogoki	5,000
	Lake Michigan at Chicago	3,200
	Welland Canal	9,000
*Scenario 7 -	Long Lac/Ogoki	5,000
	Lake Michigan at Chicago	8,700
	Welland Canal	7,000
*Scenario 8 -	Long Lac/Ogoki	0
	Lake Michigan at Chicago	8,700
	Welland Canal	7,000
*Scenario 9 -	Long Lac/Ogoki	0
	Lake Michigan at Chicago	8,700
	Welland Canal	9,000

(c) One scenario which alters diversion rates whenever the water supply to the upper Great Lakes is below normal:

	Diversion	Rate (cfs)
*Scenario 10 -	Long Lac/Ogoki	5,000 cfs
	Lake Michigan at Chicago	3,200 cfs
	Welland Canal	2,600 cfs

(d) Three scenarios for comparison of the current (1979) Long Lac/Ogoki Diversions rate and the Welland Canal Diversion rate, with those employed in the basis-of-comparison:

	Diversion	Rate (cfs)
*Scenario 11 -	Long Lac/Ogoki	5,600
	Lake Michigan at Chicago	3,200
	Welland Canal	7,000

*Scenarios selected for detailed economic review.

*Scenario 12 -	Long Lac/Ogoki	5,000
	Lake Michigan at Chicago	3,200
	Welland Canal	9,400
*Scenario 13 -	Long Lac/Ogoki	5,600
	Lake Michigan at Chicago	3,200
	Welland Canal	9,400

The above scenarios were selected for detailed evaluation because they bracket the total range of impacts which can be expected from the existing diversions or the management of diversions, singularly and in combination. The hydrologic, economic and environmental evaluation of the selected scenarios is presented in the following paragraphs.

8.5.1 Hydrologic Effects

The International Great Lakes Levels Board Study developed criteria to facilitate hydrologic evaluation of the Great Lakes system. These criteria paraphase the water level and flow requirements of the existing IJC Orders of Approval for Lakes Superior and Ontario and include similar information for Lakes Michigan-Huron and Erie. Tables and figures showing the levels and outflows which result from the application of the above noted scenarios to the 1900-1976 water supply period, in the context of these criteria, are included in Annex G to this report. A summary of the extreme water levels and outflows resulting under each of the above selected scenarios is shown in Tables 8-2, 8-3 and 8-4.

8.5.1.1. Existing Diversions

Table 8-2 presents the results of Scenarios 1 through 4. In these scenarios, the hydrologic effects of the diversion rates employed in the basis-of-comparison are evaluated singularly and in combination. Scenario 4, which reflects the combined effect, indicates that if the Long Lac/Ogoki Diversions, Lake Michigan Diversion at Chicago and the Welland Canal were not in existence, the mean level of Lake Superior would be 0.07 foot lower, Lakes Michigan-Huron would be 0.01 foot higher, Lake Erie would be 0.24 foot higher, and Lake Ontario would be 0.06 foot lower. The table also shows that the effect on the extreme levels of the regulated lakes is greater than that quoted for the unregulated lakes. This is caused by the fixed maximum and minimum flow releases incorporated in the regulation plan for the regulated lakes. On the unregulated lakes (Michigan-Huron and Erie) the outflow increases and decreases as the level rises and falls.

8.5.1.2 Varying Diversion Rates

Scenarios 5 through 10 were developed for the purposes of determining the extent to which the existing diversions could be altered, either individually or in combination, to alleviate extreme water level conditions (with primary focus on extreme high conditions). Table 8-3

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*Scenarios selected for detailed economic review.

Table 8-2
LONG LAC/OGOKI - CHICAGO-WELLAND CANAL COMBINATIONS
(WITHOUT A TRIGGER)
SUMMARY OF EXTREMES - LAKE LEVELS AND OUTFLOWS

	SCENARIOS									
	Basis-of-Comparison		1		2		3		4	
	LL/0 5000 CHI 3200 WELL 7000		LL/0 0 CHI 3200 WELL 7000		LL/0 5000 CHI 3200 WELL 0		LL/0 5000 CHI 0 WELL 7000		LL/0 0 CHI 0 WELL 0	
LAKE SUPERIOR	Feet	Tcfs	Feet	Tcfs	Feet	Tcfs	Feet	Tcfs	Feet	Tcfs
Mean	600.44	78	600.25	73	600.48	78	600.51	78	600.37	73
Maximum	601.93	123	601.83	122	601.93	123	601.93	123	601.84	122
Minimum	598.69	55	597.88	55	598.72	55	598.75	55	597.99	55
Range	3.24	68	3.95	67	3.21	68	3.18	68	3.85	67
LAKES MICHIGAN-HURON										
Mean	578.27	185	577.94	180	578.40	185	578.48	188	578.28	183
Maximum	581.16	232	580.83	226	581.28	232	581.36	235	581.20	230
Minimum	575.46	112	575.07	108	575.60	113	575.70	116	575.43	111
Range	5.70	120	5.76	118	5.68	119	5.66	119	5.77	119
LAKE ERIE										
Mean	570.76	207	570.53	202	571.08	207	570.90	210	571.00	205
Maximum	573.60	270	573.37	265	573.91	271	573.75	274	573.84	269
Minimum	568.10	152	567.84	147	568.45	152	568.25	155	568.36	150
Range	5.50	118	5.53	118	5.46	119	5.50	119	5.48	119
LAKE ONTARIO (without deviations)										
Mean	244.73	242	244.53	237	244.73	242	244.83	245	244.67	240
Maximum	249.47	310	248.34	310	249.49	310	251.29	310	248.98	310
Minimum	241.59	188	240.22	188	241.58	188	242.07	188	241.10	188
Range	7.88	122	8.12	122	7.91	122	9.22	122	7.88	122

Table 8-3
LONG LAC/OGOKI - CHICAGO-
WELLAND CANAL COMBINATIONS
(USING SUPPLY AS INDICATOR & MICHIGAN-HURON AS TRIGGER)
SUMMARY OF EXTREMES - LAKE LEVELS AND OUTFLOWS
SCENARIOS

	Basis-of-Comparison LL/O 5000 CHI 3200 WELL 7000		5 LL/O 0 CHI 3200 WELL 7000		6 LL/O 5000 CHI 3200 WELL 9000		7 LL/O 5000 CHI 8700 WELL 7000		8 LL/O 0 CHI 8700 WELL 7000		9 LL/O 0 CHI 8700 WELL 9000		10 LL/O 5000 CHI 3200 WELL 2600	
LAKE SUPERIOR	Feet	Tcfs	Feet	Tcfs	Feet	Tcfs	Feet	Tcfs	Feet	Tcfs	Feet	Tcfs	Feet	Tcfs
Mean	600.44	78	600.36	75	600.43	78	600.38	78	600.30	75	600.29	75	600.45	78
Maximum	601.93	123	601.83	122	601.93	123	601.92	123	601.83	122	601.83	122	601.93	123
Minimum	598.69	55	598.42	55	598.68	55	598.60	55	598.34	55	598.31	55	598.70	55
Range	3.24	68	3.41	67	3.25	68	3.32	68	3.49	67	3.52	67	3.23	68
LAKES MICHIGAN-HURON														
Mean	578.27	185	578.11	183	578.25	185	578.10	182	577.94	180	577.92	180	578.31	185
Maximum	581.16	232	580.92	228	581.10	232	580.86	228	580.61	225	580.59	225	581.17	232
Minimum	575.46	112	575.39	111	575.46	112	575.40	111	575.32	110	575.31	110	575.53	113
Range	5.70	120	5.53	117	5.64	120	5.46	117	5.29	115	5.28	115	5.64	119
LAKE ERIE														
Mean	570.76	207	570.65	205	570.71	207	570.64	205	570.53	202	570.48	202	570.86	207
Maximum	573.60	270	573.44	267	573.50	270	573.40	266	573.24	262	573.15	262	573.62	271
Minimum	568.10	152	568.05	151	568.09	152	568.05	151	568.00	150	568.00	150	568.31	151
Range	5.50	118	5.39	116	5.41	118	5.35	115	5.24	112	5.15	112	5.31	120
LAKE ONTARIO (without deviations)														
Mean	244.73	242	244.64	240	244.73	242	244.64	240	244.55	237	244.55	237	244.74	242
Maximum	249.47	310	248.53	310	249.44	310	248.40	310	248.05	310	248.07	310	249.58	310
Minimum	241.59	188	241.18	188	241.52	188	241.19	188	240.74	188	240.74	188	241.47	188
Range	7.88	122	7.35	122	7.92	122	7.21	122	7.31	122	7.33	122	8.11	122

presents the results of representative scenarios selected from the total array of conditions evaluated. The table shows that the greatest lowering of the maximum levels occurs under Scenario 9. This scenario reduces the Long Lac/Ogoki Diversions to zero, increases the Lake Michigan Diversion at Chicago to 8,700 cfs, and increases the Welland Canal to 9,000 cfs and is referred to hereafter as the maximum-effect diversion scenario. Under this scenario, alteration of the diversion rates would occur each time the water supply to Lakes Michigan-Huron rises above normal. The results show that by this technique, the maximum level of Lake Superior would be lowered 0.10 foot, Lakes Michigan-Huron by 0.57 foot, Lake Erie by 0.45 foot, and Lake Ontario by 1.4 feet. The large effect on Lake Ontario is due to operating under the fixed maximum and minimum releases of Regulation Plan 1958-D and reflects the full impact of all upstream actions.

Scenario 6 demonstrates the smallest impact on the high levels, since that scenario would modify the water supply the least, (increasing the Welland Canal Diversion by 2,000 cfs). It has no effect on the Lake Superior maximum level and would lower the maximum levels of Lakes Michigan-Huron by 0.06 foot, Lake Erie by 0.10 foot, and Lake Ontario by 0.03 foot.

Scenario 10, which reduces the flow through the Welland Canal during periods of below normal water supply, was developed to determine the degree that low levels could be supported. The scenario shows that the minimum and mean levels of Lake Superior would be raised by 0.01 foot, Lakes Michigan-Huron minimum raised by 0.07 foot and their mean by 0.04 foot; and Lake Erie minimum raised by 0.21 foot and its mean by 0.10 foot. The effects on the maximum levels of these lakes are 0.02 foot or less. A varying effect is shown on Lake Ontario; that is, its minimum is lowered 0.12 foot and its mean and maximum raised by 0.01 and 0.11 foot, respectively. This varying effect is due to the manner in which the outflows are manipulated under regulation of that lake.

An evaluation of the effect on the Illinois Waterway (Figure 4-3) of an increased Lake Michigan Diversion at Chicago to 8,700 cfs was carried out based on computer simulations and utilizing typical low, average and high yearly flow data. The major effect from the increased diversion of 8,700 cfs would be an increase in the weekly average water levels. Increases ranged from six feet at the Starved Rock station to four feet at the Henry and Havana Stations.

The increases in the water level were most variable during an average flow year and most consistent during a low flow year. An analysis of a high flow year was not done, due to the high improbability of the increased diversion occurring during this period of flow because natural flows exceeded bankfull conditions. During bankfull periods increased diversion would be curtailed so as to alleviate an increase in flooding conditions.

In addition to the increased water level, increased velocities in the backwater areas of the middle and lower reaches would result. Studies based on a model developed by the Chicago District, Corps of Engineers, have predicted velocity increases of about 15 percent during non-flood periods for the Illinois River near Peoria.

The final major consequence arising from the increased diversion would be the increased surface area and volume of backwater lakes. A study by Illinois Natural History Survey (INHS) indicates that during high flow conditions, bottomland lakes will expand, submerging adjacent mudflats. For example, the Peoria Pool and the LaGrange Pool will gain approximately 6,000 and 10,000 acres of backwater area, respectively, due to the increased diversion.

8.5.1.3 Basis-of-Comparison Evaluation

Section 5 of this report documents the selection of the study period and the establishment of a basis-of-comparison. Prior subsections of this section outlined the selected diversion scenarios which were evaluated against that basis-of-comparison. Since the start of the study in 1977, water supplies to the Great Lakes system have continued to be above normal and certain management and contractual decisions have been implemented, resulting in variations from the basis-of-comparison which in turn affect impact assessments. Each of these anomolies is discussed briefly below.

Long Lac/Ogoki Diversions. Section 4 of this report describes the exchange of notes in 1940 between the Governments of Canada and the United States, as related to these two diversions and the Canadian consideration for power diversion on the Niagara River related thereto. By this exchange of notes, which is also referred to in the Niagara Treaty of 1950, Ontario Hydro was authorized by the Canadian Government, with the concurrence of the United States Government, to use at the power generation stations located on the Niagara River, or in the Welland Canal, 5,000 cfs of the water diverted from the Albany River basin. The figure of 5,000 cfs was an estimate of the average flow that would be diverted. The actual diversions since their inception have averaged 5,600 cfs. Table 8-4 (Scenario 11) shows the effects of the additional 600 cfs on the basis-of-comparison. The table shows that the mean, maximum and minimum of all lakes would be higher than the adopted basis-of-comparison. On Lakes Superior, Michigan-Huron and Erie this increase is not more than 0.04 foot. The maximum and minimum levels of Lake Ontario would be higher by 0.13 and 0.10 foot, respectively. The relatively larger effects on the extreme levels of Lake Ontario is explained by the size of the lake in relation to other lakes of the system and the fact that this lake is regulated and has fixed minimum and maximum releases.

Welland Canal. Figure 4-6 of Section 4 shows the amount of water diverted from Lake Erie through the Welland Canal over the historic period. As noted in Section 4, the rapid increase of water requirements in the canal ended in about 1951 and fluctuated above and below an average of 7,000 cfs (the actual average from 1950-1976 was 7,600 cfs). The selection

Table 8-4
COMPARISON OF VARIANCE IN BASIS-OF-COMPARISON VALUES
SUMMARY OF EXTREMES

	Basis-of-Comparison LL/O 5000 CHI 3200 WELL 5000		SCENARIOS 11 LL/O 5600 CHI 3200 WELL 7000		12 LL/O 5000 CHI 3200 WELL 9400		13 LL/O 5600 CHI 3200 WELL 9400	
LAKE SUPERIOR	Feet	Tcfs	Feet	Tcfs	Feet	Tcfs	Feet	Tcfs
Mean	600.44	78	600.46	78	600.42	78	600.44	78
Maximum	601.93	123	601.95	123	601.93	123	601.95	123
Minimum	598.69	55	598.73	55	598.66	55	598.72	55
Range	3.24	68	3.22	68	3.27	68	3.23	68
LAKES MICHIGAN-HURON								
Mean	578.27	185	578.31	186	578.22	185	578.26	186
Maximum	581.16	232	581.19	233	581.10	232	581.14	233
Minimum	575.46	112	575.50	113	575.42	112	575.47	113
Range	5.70	120	5.69	120	5.68	120	5.67	120
LAKE ERIE								
Mean	570.76	207	570.78	208	570.64	207	570.67	208
Maximum	573.60	270	573.63	271	573.49	270	573.52	271
Minimum	568.10	152	568.12	152	567.97	152	568.00	152
Range	5.50	118	5.51	119	5.52	118	5.52	119
LAKE ONTARIO								
Mean	244.73	242	244.75	243	244.73	242	244.75	243
Maximum	249.47	310	249.60	310	249.42	310	249.62	310
Minimum	241.59	188	241.69	188	241.59	188	241.69	188
Range	7.88	122	7.91	122	7.83	122	7.93	122

of the 7,000 cfs value for the basis-of-comparison was fairly representative of conditions existing in 1977, at the study's inception. However, development since 1976 has further increased water needs of users of the canal (see Figure 4-6). The net effect of these changes has been to increase the average flow (over the period 1950-1980) through the Welland Canal from 7,600 (1950-1976 average) to about 7,800 cfs. Currently (1980) the power requirements are about 6,900 cfs; navigation requirement has risen steadily and is currently about 1,300 cfs; and the water needed for domestic supply and dilution is in the order of 1,000 cfs; for a total Welland Canal Diversion of 9,200 cfs (see Figure 4-8). Based on the projected navigation requirement in the future, it is expected that the flow through the canal could rise to 9,400 cfs.

Table 8-4 (Scenario 12) shows the effect of the 9,400 cfs rate, in comparison to the 7,000 cfs employed in the basis-of-comparison. The table shows that the mean, maximum and minimum levels would have stayed the same or would have been lowered by as much as 0.10 foot. On Lake Superior the range would be increased by 0.03 foot, Lakes Michigan-Huron decreased by 0.02 foot, Lake Erie increased by 0.02 foot and on Lake Ontario decreased by 0.05 foot.

Combined Long Lac/Ogoki Diversions and Welland Canal. The combined hydrologic effect of the above-noted variations from the selected basis-of-comparison, is shown on Table 8-4 under Scenario 13. The table shows no change to the mean level of Lake Superior, which is regulated; a raising of the mean level by 0.02 foot on regulated Lake Ontario; and a lowering of the levels on the unregulated lakes by less than 0.10 foot. On Lake Superior the impact would increase the maximum and minimum level by 0.02 foot and 0.03 foot, respectively; on Lakes Michigan-Huron, lower the maximum level by 0.02 foot and increase the minimum level by 0.01 foot; on Lake Erie, lower the maximum and minimum levels by 0.08 and 0.10 foot respectively; and on Lake Ontario raise the maximum and minimum levels by 0.15 foot and 0.10 foot respectively. Again, the relatively large effects on the extreme levels of Lake Ontario are due to regulation with fixed maximum and minimum releases.

8.5.2 Economic Effects

The detailed economic evaluation presented herein was performed by the International Lake Erie Regulation Study Board, using the methodology described briefly in Section 8.3. As noted above, Scenarios 2, 3 and 4 were not economically evaluated, since these evaluations would entail determining the costs of development of an alternate water supply for the City of Chicago and for other modes of transportation between Lakes Erie and Ontario. This exercise is beyond the scope of this study and hence those scenarios are not referred to in the following discussion.

8.5.2.1 Existing Diversions

Table 8-5 summarizes the economic impacts on the coastal zone, navigation and power interests, assuming the Long Lac/Ogoki Diversions were non-existent (Scenario 1). The table shows annual benefits to coastal zone

Table 8-5
SUMMARY OF ECONOMIC IMPACTS
EXISTING DIVERSIONS
(ANNUAL VALUES IN $1000)
SCENARIO 1
(LL/0-0; Chi-3200; Well-7000)

Coastal Zone	
United States	+ 3,818
Canada	+ 980
Subtotal	+ 4,798
Navigation	
United States	-11,369
Canada	- 6,226
Subtotal	-17,595
Power	
United States	-14,557
Canada	-25,689
Subtotal	-40,246
Total*	-53,043

*Not included is an estimated $4,000,000 annual loss to the pulp and paper industry on the Aguasabon River.

interests of $4.8 million, with losses to navigation interests of $17.6 million and to power interests of $40.2 million. The table further shows that benefits derived by the coastal zone interests would accrue mainly to the United States, while the losses to power interests would be predominately Canadian. In total, the annual value of losses exceed economic benefits by about $57.0 million, including the loss to the pulp and paper industry located on the Aguasabon River.

8.5.2.2 Varying the Existing Diversion Rates

Table 8-6 summarizes the economic impacts on the coastal zone, navigation, power and recreational interests on the Great Lakes when the diversions are managed to change the regime of Great Lakes levels and outflows. The table shows that in all cases (except Scenario 10) benefits would accrue to the coastal zone and recreational beach interests. Also, losses would accrue in all cases (except Scenario 10) to commercial navigation interests and recreational boating interests. A similar pattern exists for power interests, except under Scenario 6 which provides a net benefit. Overall, the table shows that large net economic losses result to the users of the system whenever the diversions are managed to alter the water supply to the Great Lakes. Only under Scenarios 6 and 10, which alter only the flow through the Welland Canal, is the loss relatively small or a net economic gain (Scenario 6) realized. Scenario 9, which provides a maximum net economic gain to coastal zone and recreational beach interests of about $7.8 million, produces losses to the other interests, including the pulp and paper interests on the Aguasabon, of $80.7 million. All other scenarios produce lesser impacts.

One of the major results of an increased Lake Michigan Diversion at Chicago is the overall change in the economy of the Illinois Waterway. Five major concerns are: commercial navigation, power generation, residential flood damages, increased pumping costs for the agricultural system and increased costs to local duck clubs.

Commercial navigation on the Illinois Waterway is affected both beneficially and adversely. Increased water elevations lead to savings for shippers by decreasing lockage delays; however, velocities associated with flow increases cause tie-up time to increase and reduce the speed on upstream travel. Nevertheless, a study of the costs involved indicated that benefits to commercial navigation will be $154,000/year for the increase to 8,700 cfs.

Impacts to recreational boating on the waterway are expected to be minimal. Velocity increases are not sufficient to impact on boat usage; additional water areas will become available for use by shallow draft boats in the lower river reaches.

An increased diversion provides both beneficial and adverse results for power generation along the waterway. The Lockport power plant stands to benefit from increased output potential due to the increased flow; however, the Marsailles power plant will suffer losses, due to surpassing its optimum usage at the increased flow rate with concurrent

Table 8-6
SUMMARY OF ECONOMIC IMPACTS
VARYING DIVERSION RATES
(ANNUAL VALUES IN $1000)

SCENARIOS

	5	6	7	8	9	10
	LL/O 0 CHI 3200 WELL 7000	LL/O 5000 CHI 3200 WELL 9000	LL/O 5000 CHI 8700 WELL 7000	LL/O 0 CHI 8700 WELL 7000	LL/O 0 CHI 8700 WELL 9000	LL/O 5000 CHI 3200 WELL 2600
Coastal Zone						
United States	2,544	499	2,722	4,519	4,883	-696
Canada	841	84	857	1,091	1,134	-129
Subtotal	3,385	583	3,579	5,610	6,017	-825
Navigation						
United States	-4,432	-385	-3,912	-8,745	-9,143	1,252
Canada	-2,190	-205	-1,874	-4,362	-4,617	774
Subtotal	-6,622	-590	-5,786	-13,107	-13,760	2,026
Power						
United States	-6,888	-37	-37,381	-44,449	-44,527	19
Canada	-13,129	1,010	4,019	-17,536	-16,808	-3,991
Subtotal	-20,017	973	-41,400	-61,985	-61,335	-3,972
Recreational Boating (1)						
United States	-579	-253	-767	*	-1,635	*
Canada	*	*	*	*	*	*
Subtotal	-579	-253	-767	*	-1,635	*
Recreational Beaches (1)						
United States	756	610	659	*	1,807	*
Canada	*	*	*	*	*	*
Subtotal	756	610	659	*	1,807	*
Total	-23,077**	1,323	-43,715	-69,482**	-68,906**	-2,771

*Data not available.
**Not included is an estimated $4,000,000 annual loss to the pulp and paper industry on the Aguasabon River.

(1) Only the area below Lake Huron.

reductions in net head. Overall though, the net benefits tend to favor the increased diversion, at 8,700 cfs, the net benefits are estimated to be $337,000.

Residential flood damages along the waterway are expected to increase with the increased water levels. Residential damages were determined for each reference point along the waterway. Annual incremental damages were then computed for both low and average flow years. The results indicate that for low flow years the losses would be $493,000/year and for average flow years the losses would be $301,000/year. Incremental flood damages due to the diversion would not occur during a high flow year, since no increased diversion would be allowed.

The Illinois Waterway agricultural system will be affected by the higher river levels due to the fact that pumping to dewater leveed farm land will increase. Pumping costs increase approximately $55,000/year during low flow, and $35,000/year during average flow. Another effect will be crop loss and the reduction in output.

Commercial timber production in the waterway's bottomland and forests is expected to be impacted through a reduction of access to the forests and reductions to the life expectancy of bottomland timber.

The final economic concern to be addressed is the loss which will be suffered by local duck clubs. Increased flooding and pumping costs will be incurred impacting on their controlled marshlands. Some habitat destruction may also occur.

8.5.2.3 Changes in the Basis-of-Comparison

As noted in Section 8.5.1.3, diversion rates selected for use in the basis-of-comparison have not remained at the selected levels since the start of the study, resulting in economic impacts on the various users of the system. Table 8-7 presents the economic impacts derived by comparing the adopted basis-of-comparison rates with an adjusted basis-of-comparison (which include the effects of these changes), assuming they would have existed over the total study period (1900-1976).

Table 8-7 shows that if the Long Lac/Ogoki Diversions (Scenario 11) had provided inflows to the system (over the study period) at an average of 5,600 cfs rather than the adopted rate of 5,000 cfs, an average annual net benefit to the system of $11.3 million would have been produced. This figure results from losses to the coastal zone interests of $0.7 million and benefits to navigation and power of $12.0 million. Scenario 12 indicates the effect of increases in flow in the Welland Canal from 7,000 cfs to 9,400 cfs. The table shows net annual benefits to coastal zone and power interests of $2.6 million, and losses to navigation interests of $2.0 million, for a net average annual benefit of $0.5 million. Scenario 13 combines both these impacts and shows that the losses to coastal zone interests resulting from the Long Lac/Ogoki increase, and the losses to navigation interest from the increased Welland Canal flow have been almost offset. This scenario produces net annual benefits to coastal zone, power,

Table 8-7
SUMMARY OF ECONOMIC IMPACTS
VARIANCE IN BASIS-OF-COMPARISON VALUES
(ANNUAL VALUES IN $1000)

SCENARIOS

	11 LL/O 5600 CHI 3200 WELL 7000	12 LL/O 5000 CHI 3200 WELL 9400	13 LL/O 5600 CHI 3200 WELL 9400
Coastal Zone			
United States	-502	895	349
Canada	-175	154	-73
Subtotal	-677	1,049	276
Navigation			
United States	1,185	-1,266	-29
Canada	604	-748	-133
Subtotal	1,789	-2,014	-162
Power			
United States	8,071	36	8,064
Canada	2,159	1,482	3,702
Subtotal	10,230	1,518	11,766
Recreational Boating (1)			
United States	*	*	-232
Canada	*	*	*
Recreational Beaches (1)			
United States	*	*	591
Canada	*	*	*
Total	11,342	553	12,239

(1) Only the area below Lake Huron.

*Data not available.

and recreational beach interests of $12.6 million, and losses to commercial navigation and recreational boating interest of $0.4 million, for a net average annual benefit to the system of $12.2 million.

8.5.2.4 Sensitivity Analyses of Power Impacts

Tables 8-5, 8-6 and 8-7 show that under each of the conditions evaluated, the major impact of changes in the diversion rates is on the power industry. In addition, as noted in the evaluation methodology, there was a large difference in the value of replacement power used for the United States as compared to that for Canada. This prompted a sensitivity analysis employing the cost of an alternative source of replacement power for the United States namely, purchased hydro-power from Canada. The selling price of exported Canadian energy is currently around 30 mills/KWH, whereas the cost of oil-produced energy in New York State is approximately 110 mills/KWH.* Applying the Canadian selling price to the diversion management scenario having the greatest dollar impact (Scenario 8 - Long Lac/Ogoki-0 cfs; Chicago-8,700 cfs; Welland-7,000 cfs) would yield a 71 percent reduction in the value of power losses to the New York system, from $44.4 million to $12.9 million (see Table 8-8) and would increase the value of Canadian power produced in Ontario and Quebec from $15.9 and $1.6 million, respectively, to $28.3 and $6.5, respectively.

An adjustment of the figures presented in Table 8-6 to reflect this analysis would reduce the total reported net economic loss of $69.5 million to $55.4 million. Despite this adjustment, the overall economic conclusion on each of the management scenarios would remain the same; that is, each of the diversion management scenarios would produce net economic losses to the system.

A second comparison is also presented in Table 8-8, that is, employing a value of 63.06 mills/KWH for replacement power in the New York State system. This also provides for a reduction in impact; however, it does not change the overall conclusion that diversion management produces large economic losses to the system.

To clarify the future long-term direction of power generation in New York, inquiries were made of the U.S. Department of Energy (DOE). DOE is continuously studying the total energy picture in the United States, using a variety of scenarios and sensitivity analyses, as part of its commitment to bring about a reduction in oil consumption and dependence on foreign sources. Eventual elimination of oil use by utilities is a major objective of the DOE program. While there is no long-term DOE perspective specific to New York State, one recent DOE study estimates that substantial quantities of oil would still be required by utilities in the year 2000, in an area that includes the bulk of the state's oil-fired generation. This is the October 1980, Section 13a Energy Technology Scenarios from the Office of Assistant Secretary for Environment for use in Water Resources

*Amortized cost over study period. For details refer to the International Lake Erie Regulation Study Report, 1981.(13)

Table 8-8
POWER LOSSES SENSITIVITY ANALYSES

Utility	Economic Impact on Power - $1,000 (Annual amortized cost) As Reported* (Scenario 8)	PASNY @ 30 mills/KWH	All Utilities @ 30 mills/KWH	PASNY @** 63.06 mills/KWH
New York System	- 44,425	- 12,862	- 12,862	- 25,808
Ontario Hydro	- 15,896	- 15,896	- 28,310	- 15,896
Hydro-Quebec	- 1,640	- 1,640	- 6,501	- 1,640
Upper Michigan	- 24	- 24	- 216	- 24
Total	- 61,985	- 30,422	- 47,889	- 43,368

	Annual Amortized Cost of Replacement	
	Energy - mills/KWH	Peak - $/KW
New York System	110.6	70.0
Ontario Hydro	17.24 (day)	
	12.12 (night)	
	15.53 (wtd. av.)	33.08
Hydro-Quebec	7.568	
Upper Michigan	3.36	28.33

*As reported numbers are based upon the above noted Annual Amortized Cost of Replacement (also see Section 8.3.3.3).

**Annual amortized cost of replacement power; mean between PASNY and Ontario Hydro rate.

Council assessments. Depending on the world oil price assumed, the amount of the fuel projected for that year is in the order of 40 million barrels. In terms of Btu heat content, this is well in excess of coal-fired and nuclear generation combined. This would tend to support PASNY's use of oil-fired generation for study purposes as a source of replacement energy in New York. Although DOE studies indicate that beyond 2000, the nation's demand for electric power will be met using a combination of coal, nuclear, and renewable resources, efforts to particularize likely scenarios are subject to a high degree of uncertainty and speculation.

8.5.3 Environmental Effects

Only the maximum-effect diversion scenario was evaluated for environmental impacts. This scenario would have the greatest effect on levels and flows. Lake levels resulting from this scenario are presented in Tables 8-13 and 8-14 (page 8-41).

8.5.3.1 Fisheries

Although the changes in lake levels which would occur as a result of selected diversion scenarios are small when compared with natural fluctuations, they may have some effect on fish, especially in the shallow inshore areas of the lower Great Lakes and connecting channels. A review of the literature on Great Lakes fishery indicated that there was a particular lack of fisheries-related information for the nearshore area especially dealing with the effect water level changes would have on fish which use this very productive zone for spawning, nursery, feeding, overwintering, or migration activities. Because the environmental evaluation was limited to the use of existing information, the determination of cause-effect relationships between water level changes and the impacts on fish was based largely on inference and was qualitative rather than quantitative.

In general, the fisheries resource may be affected by the implementation of a diversion plan in several ways, including:

(1) reduction or change in shallow water habitat used by fish during critical stages in their life cycles;

(2) reduction in total hypolimnion oxygen resources and volume (Summer habitat for coldwater fish species); and,

(3) changes in seasonal water levels or rate of change in water levels, especially during the spawning seasons.

Change in Shallow Water Habitats

Reductions in water levels such as those which would occur with the maximum-effect diversion management scenario could result in changes in the vegetative composition of lakeshore wetlands (see Wetlands/Wildlife). Generally, such changes would become manifest as a reduction in the area of open water/submergent/floating leaved vegetation zones, and as an increase in the area of the emergent and sedge/meadow zones. These changes would be detrimental to some fish species since the changes would cause a reduction in the available nearshore spawning and/or nursery areas. The availability of certain food sources could also be reduced as leafy hydric macrophytes are more densely populated with invertebrate forage organisms than the emergent macrophytes. Lower lake levels could reduce the availability of these food sources by altering the abundance of the various vegetative types as described above.

The extent to which each lake could be affected would depend largely on the amount of associated wetlands and shallow embayments. Of the Great Lakes fisheries, the Lake Superior fisheries should be the least affected by the diversion scenario as the United States shoreline of Lake Superior has a very limited littoral zone and the Canadian shoreline has almost none. Shallow water areas, such as Cecil Bay, Sturgeon Bay, and Green Bay in Wisconsin, are considered Lake Michigan's most important fish spawning and habitat sites. These areas, as well as the large, channel-connected lakes such as Macatawa, Manistee and Charlevoix, along the eastern shore of Lake Michigan would probably be impaired by lowering the level of the lake.

The shoreline of Lake Huron is 29 percent marshland with major shallow water areas occurring in the province of Ontario along the northshore of Georgian Bay and in the North Channel, and in Michigan's Saginaw Bay. Saginaw Bay alone accounts for over half of this area and contains seven wildlife areas for public use. Lower water levels may adversely impact fish populations in these areas, but the attempts of one study to relate yellow perch year-class strength with lake levels in Saginaw Bay could not establish such a relationship.

In Lake Ontario the Bay of Quinte in the province of Ontario and the marshland along the New York shore have been identified as two areas where impacts to nearshore fish habitat could occur. Lowering the water level by the amounts indicated with the scenario could eliminate or impair the use by fish of a portion of these areas.

In Lake Erie, the extensive littoral areas would be most affected by lake level changes. Long Point Bay and Rondeau Bay in the province of Ontario, Sandusky Bay and Maumee Bay in Ohio, and Presque Isle Bay of Pennsylvania are areas where dramatic effects could occur with only minor changes in lake level. Their shallow nature and sand spit formation make them very sensitive to water level changes. Because of areas like these, Lake Erie has been identified as the lake that would experience the greatest change in nearshore fish habitat due to the selected maximum-effect diversion scenario. Fishery impacts on the other Great Lakes would be similar but of reduced magnitude.

It should be noted that with respect to all Great Lakes wetlands, lakeward reestablishment could occur, depending on the physical constraints (e.g., depth contours, shoals, embayments, etc.), and the availability of suitable substrate. Such wetlands reestablishment could reduce the magnitude of the loss to the fishery, but is not expected to completely eliminate it.

Reduction in Hypolimnion Volume

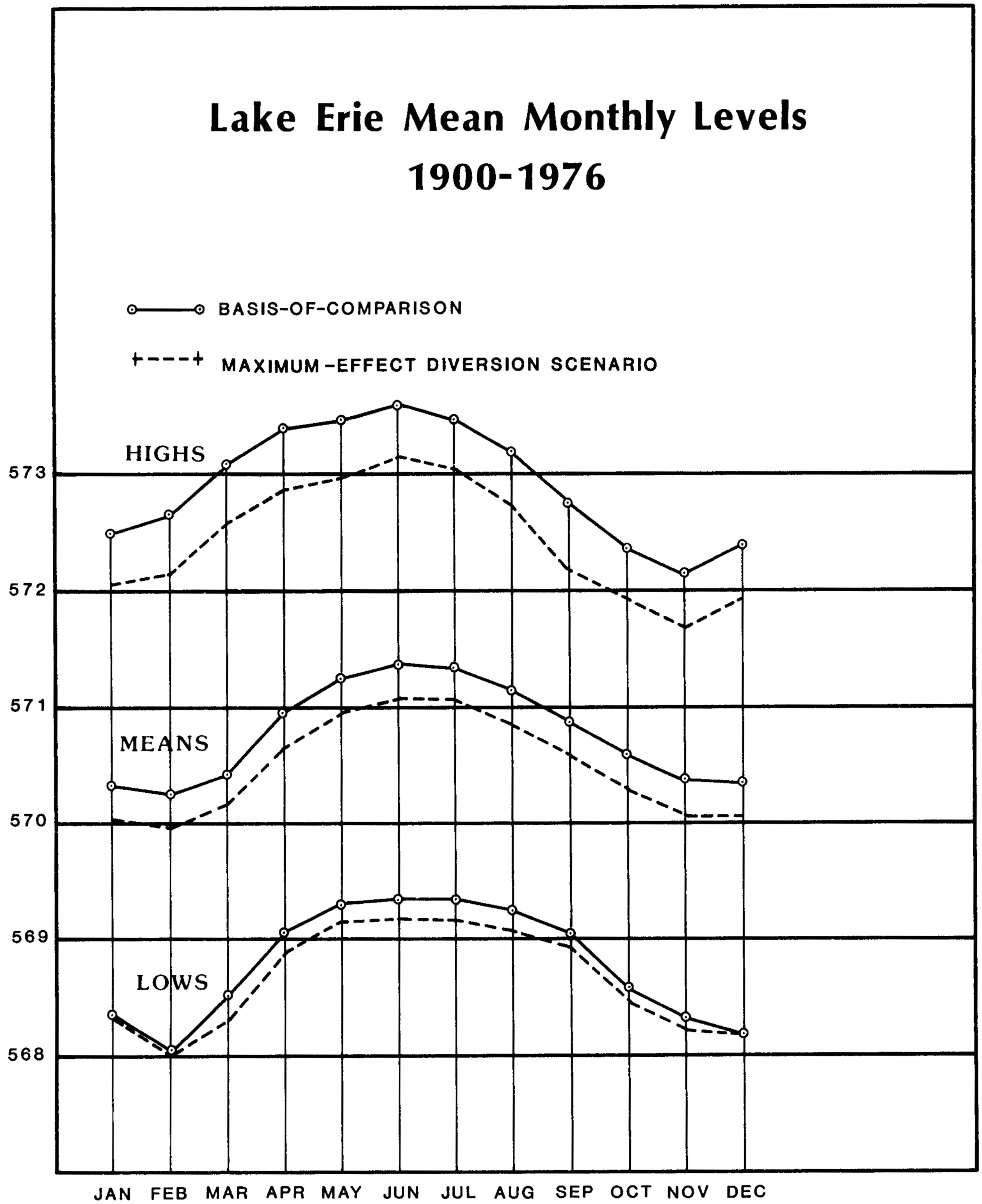
The International Lake Erie Regulation Study (ILERS)[13] indicated that reductions in hypolimnion volume and associated oxygen resources were likely under the regulation plans considered for that lake. ILERS results indicate that a one-foot lowering of Lake Erie could decrease the central basin hypolimnion volume and oxygen resources by as much as 15 percent (see Section 8.5.3.3). The diversion scenario would result in a mean Lake Erie water level decrease approximately 40 percent less than this. Consequently, the loss of hypolimnion oxygen resources and volume would be considerably less severe.

Since the Lake Erie eastern basin has a hypolimnion of much larger volume than either the western or central basins, a reduced hypolimnion volume in the eastern basin is not as significant. Cold water fish species need only to migrate downward to find suitable habitat. Also, it has been documented that the cold water species of Lake Erie migrate from west to east in the summer. Such seasonal migration should lessen the adverse effects to Lake Erie cold water fisheries, as suitable habitat would be available in the eastern basin to accommodate this movement.

The hypolimnion volumes of Lakes Ontario, Michigan, Huron and Superior are far larger than those of Lake Erie. Fractional reductions in the volume of the hypolimnia of these lakes would not produce any serious impacts on the fisheries of the lakes. A slight downward migration of cold water fish species would be the only effect of lower lake levels. The reductions in hypolimnion volume for these lakes are quantified in the Water Quality section (Section 8.5.3.3).

Change in Seasonal Water Levels

When compared to the basis-of-comparison, the maximum-effect diversion scenario would not cause either a seasonal shift in the occurrence of high and low water levels, or a significant change in the range of levels within the annual cycles. The mean monthly Lake Erie levels for both the basis-of-comparison and the maximum-effect diversion scenario are shown in Figure 8-1. Similarly, in Lakes Huron, Michigan and Superior all levels would be reduced, but the seasonal level variation pattern is unchanged with the annual low water level occurring in February. Lowered water levels during this period would reduce the already limited habitat available to the many species that return to the nearshore zone once the ice cover forms. The increased bottom scouring and uprooting of aquatic vegetation caused by more ice-covered shallow water zones could also adversely affect the nearshore fish stocks.



Lake Erie Mean Monthly Levels
1900-1976
BASIS-OF-COMPARISON
MAXIMUM-EFFECT DIVERSION SCENARIO
HIGHS
MEANS
LOWS
573
572
571
570
569
568
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

Figure 8-1

Fish Species Reactions to Water Levels

Little is known about the reaction of fish populations to various water levels in the Great Lakes. It is known that with losses of certain vegetation types and changes in shallow water habitat, fish populations also change. Seasonal variations which are different from the normal historic occurrences could possibly change spawning activities of some fish species as there is a reliance by spawning fish on water temperature which, in turn, is influenced by the depth of the water and also by the rate at which the water levels rise or fall.

Although the six research papers found describing attempts to relate lake level changes to year-class strength show no direct relationship between the two, a correlation was found between water levels and the abundance of young-of-the-year fish of some species in the western basin of Lake Erie. As determined by using linear regression techniques (Table 8-9), some fish appear to do better during high water periods while others do better during low water periods.

Table 8-9
RELATIONSHIP BETWEEN YOUNG-OF-THE-YEAR FISH POPULATIONS AND WATER LEVELS FOR LAKE ERIE WESTERN BASIN, 1959-1974*

Species	Correlation Coefficient	Percent Change BOC/Diversion Scenario**
Alewife	+0.72	-29.2
Smelt	+0.67	-22.2
Gizzard Shad	+0.64	- 8.8
Walleye	+0.41	-11.5
Y. Perch	-0.40	+13.9
Trout Perch	-0.53	+13.2

*Data from young-of-the-year population assessments made by the USFWS, Sandusky, Ohio.

**The Percent Change is the change expected with the maximum-effect diversion scenario as compared to the basis-of-comparison (BOC). A negative value indicates a reduction in young-of-the-year as a result of reduced water levels with the diversion scenario.

Only those species which showed a correlation coefficient within the 90 percent confidence limits are presented in Table 8-9. Other species which were tested but showed little or no correlation to water levels include: white bass, freshwater drum, channel cat, emerald shiner, spottail shiner, carp, goldfish, and brown bullhead. These findings reinforce those of Beeton and Rosenberg (1968)[4] who reported that the commercial catch of yellow perch from Lake Erie (1935-1958) was inversely related to water levels while walleye production was directly related to water levels.

Conclusion

Overall, there is insufficient information on Great Lakes fisheries and how they are affected by changes in water levels of the magnitude which would be experienced under a diversion scenario to draw any definitive conclusions concerning possible impacts. However, the data which are available suggest that decreases in water levels would probably alter the shallow areas of the Great Lakes in a way which would have a negative impact on fishery resources.

8.5.3.2 Wetlands/Wildlife

Wetland Types

The ecological effect of altering the levels of the Great Lakes is probably most directly felt by the contiguous wetlands and their associated fish and wildlife. Due to the shallow nature of these areas, small fluctuations in water levels could represent large percentage changes and may result in the complete dewatering of some areas. These wetlands are important as they are unique habitat providing resources for both aquatic and terrestrial species.

The extent to which specific wetlands would be affected by lake level alterations depends upon the morphology of those wetlands. The International Lake Erie Regulation Study Board (1981)[13] identified seven types of wetlands found in the Great Lakes region (Figure 2-3). Those wetlands where migration of the vegetative zones is restricted are most likely to be damaged by lake level fluctuations. Jaworski, et al (1979)[15] reported that few Great Lakes wetlands have unobstructed environmental gradients which permit lateral displacement of the zonal vegetation during lake level changes. It appears, therefore, that Great Lakes wetlands are sensitive to lake level management.

Wetland Area

Total inventories of Great Lakes wetlands are currently incomplete, but the Great Lakes Basin Commission (1978)[7] reported that roughly seven percent of the shoreline of the Great Lakes and their connecting waterways are classified as wetlands. The International Lake Erie Regulation Study Board (1981)[13] inventoried the lower Great Lakes (including the St. Clair River, Lake St. Clair, the Detroit River, Lake Erie, the Niagara River, Lake Ontario and the St. Lawrence River), identifying 151,760 acres of wetlands.

Effects of Lake Levels on Wetland Size

The only major study concerning the impact of lake levels on Great Lakes wetland areas was conducted by Jaworski et al (1979).[15] Of the seven wetlands studied, Jaworski found that total wetland area decreases with increased lake levels due to a die back of lacustrine vegetation in the littoral zone under high water conditions. Over the areas studied, the average reduction in wetland area due to a change from extreme low to extreme high water levels was about 13 percent (Table 8-10).

Table 8-10
EXTENT OF WETLANDS AT VARIOUS LAKE LEVELS
BY WETLAND STUDY AREA, IN ACRES*

Site	Low Stage	High Stage
Oconto (L. Michigan)	1,650	1,157
Betsie (L. Michigan)	373	241
Tobico (L. Huron)	1,260	1,225
Tuscola (L. Huron)	60	43
Dickinson (L. St. Clair)	2,800	2,470
Woodtick (L. Erie)	2,395	2,119
Toussaint (L. Erie)	1,766	1,720
TOTALS	10,304	8,975

*From Jaworski, et al (1979)[15]

Plant Community Changes

In addition to the changes in total wetland area associated with various lake levels, the relative importance of the plant communities within the wetlands also changes. Four major vegetation zones based on water depth requirements have been determined for the wetlands along the Great Lakes. These zones are: 1) shrub/tree; 2) sedge/meadow; 3) emergents; 4) open water/floating-leaved/submergents.

Changes in water levels will change the size and value of these vegetation zones. Details are illustrated in Annex G.

Effect of Diversions

A more complete analysis of the effect of lake level changes on wetland vegetation was prepared using data from Dickinson Island Marsh and Toussaint Marsh studies. Wetland vegetation and water level changes as associated with the diversion scenarios are tabulated and displayed in Annex G.

Generally, during high water periods there are increases in the open water/submerged vegetation zones and decreases in sedge/meadow and emergent categories. At low water level periods the opposite occurs.

To benefit the greatest diversity of wetland-dependent wildlife, many researchers suggest the hemi-marsh would be the best environment. This type of marsh consists of open water/submergents and emergent sedge/meadow type vegetation in a one-to-one ratio. In most cases, this vegetation structure occurs with sustained levels above the long-term basis-of-comparison mean. Such levels would be reduced by implementing the diversion scenario.

Visible changes in wetland vegetation composition could result from long durations of relatively unfluctuating water levels. To maintain the wetland diversity, periodic highs and lows of the magnitude of those in the past should occur. The high levels bring in nutrients, and flush the wetland, thinning all dense emergent and sedge vegetation; the low levels allow new vegetation to regenerate, keeping the wetland in early successional stages. The general responses of the seven wetland types to a consistent decrease in water levels are presented in Table G-64 (Annex G). The reduced range in water levels which would be experienced with the diversion scenario could lead to more homogeneous plant communities. These communities would probably revert, through succession, to a sedge/meadow and, if dry conditions persisted, eventually to an upland state along the landward edge.

Effects on Wildlife

Of the publications reviewed, very few establish a direct relationship between water levels on the Great Lakes and bird populations. One document, however, did relate changes in the size of the Great Lakes Ring-billed Gull population to changes in lake levels. It was noted that their numbers increased almost five-fold in the 1960s after remaining fairly stable from 1940 to 1960. The author attributed this explosion to lower lake levels and the consequent increase in the availability of suitable breeding territory along with an abundant food supply afforded by large populations of alewife.

Another paper, dealing with the effects of Lake Erie water levels on migrating shorebird populations during the period 1966 to 1971, reports significant declines in shorebirds at Long Point. The authors attribute this decline, particularly noted in those species that feed in the small pools along the beach, to rising lake levels which reduce the quality of the beach pool habitat.

Although most of the papers reviewed suggest that shorebirds would be favored by low water levels and subsequent freedom from rapidly rising water during the nesting season, it is noted that the changing water levels periodically flood some shoreline areas thereby repressing plant succession and maintaining open areas for nesting. This mechanism provides some degree of population stability. It should also be noted that large expansions of the population of these birds are often accompanied by disease epidemics creating large die-offs of water and shorebirds.

Although no direct evidence could be found in pertinent Great Lakes literature that fluctuations in water levels had reduced the reproductive success of waterfowl, many of the papers did express the opinion that the quality of waterfowl habitat deteriorated with lower lake levels. Good quality staging areas require "hemi-marsh" conditions, which provide adequate open water areas, food and cover plants. Although a slight increase in the number of nesting waterfowl may be noticed as a result of increased sedge/meadow zones, any increase would be insignificant when compared to the reduction in the quality of the staging habitat. Dennis and Chandler (1974)[5] note that the primary importance of the Great Lakes shoreline wetlands for waterfowl is as a migration-staging habitat for the birds in the Atlantic and Mississippi Flyways.

Not all species would necessarily be adversely affected by the maximum-effect diversion scenario. The predicted increase in sedge/meadow and emergent areas would benefit red-winged blackbirds, swamp sparrows, yellow throats and some terrestrial animal species (white-tailed deer, cottontail rabbit), while wetland-dependent species such as waterfowl, coots, gallinules and black terns would suffer (see Table 8-11). It is possible, however, that all wildlife could be negatively affected if the low water conditions created by a diversion scenario stimulated the diking and development of additional wetlands.

Although it appears likely that a reduction in water levels would induce the environmental responses outlined in the previous sections, it is not possible to assess the overall magnitude of these changes with the data presently available.

Impact on Endangered and Threatened Species

A decrease in water levels in the Great Lakes would most directly affect endangered and threatened species through changes in the depth of the shallow water regions. The species most likely to be affected are those which depend upon wetlands for habitat during some stage of their life cycle, as small changes in water level could greatly change the size of marsh and wetland areas.

Of the endangered or threatened species in the Great Lakes basin the mammals, birds and reptiles would probably be least affected due to their mobility. Although many of these species (listed in Section 2) depend upon wetland habitat for food, many are transient and all are probably capable of moving the short distances which may be required if lowering lake levels only result in a lateral shift of suitable vegetation zones. However, one research paper attributed the reduction in nesting of the Piping Plover on the south beach of Long Point, Ontario, to the rising water levels during the period 1967-1971. In this case the increased water levels apparently reduced the availability of nesting sites, adversely affecting bird populations.

Of the 11 fish species listed as threatened or endangered in the Great Lakes, five of the members of the genus <u>Coregonus</u> are not normally found at depths of less than 30 feet; the sixth <u>C. artedii</u>, may use shallow water for spawning but is not restricted to such areas (Scott and Crossman, 1973)[17]. The remaining five fish species are found in shallow water areas during portions of their life cycles, but are more closely related to stream or reef areas than to marshes and wetlands. Although stream habitats are expected to be unaffected by reduced lake levels, some changes may occur in the amount of reef area which is at a depth suitable for spawning. Any impact which does occur due to this area loss or to changes in the availability of food items for fish is not likely to be significant.

It is not possible to predict impacts upon the individual species of mussels and snails listed, but many of these species are most commonly

Table 8-11

WILDLIFE USE AND OTHER FUNCTIONS OF COASTAL WETLANDS AT LOW AND HIGH WATER LEVELS. (From Jaworski, *et al*, 1979)[15]

Use/Function of Wetlands	Low Water*	High Water*
A. Use by Wildlife:		
Blue-winged teal (breeding)	- - - ----------	
Red-winged blackbird	----------- - - -	
Mallard (breeding)	- - ----------	----- - - -
Short-billed wren	---------- - -	
Muskrat	- - - ----------	-------- - - -
Black tern		- - ---------
Yellowheaded blackbird		- - ---------
Great blue heron	- - - -	-----------------
Belted kingfisher	- - - -	-----------------
Crayfish	- - - -	-----------------
Frogs and turtles	- -	-----------------
Fish spawning (N. pike)	-	-----------------
Forage fish	-	-----------------
Dabbling ducks (feeding)	-- - - --------	-------- - - - --
B. Other Functions:		
Peat accumulation	------- - - - -	
Sediment trapping	------- - - - -	
Hemi-marsh	- - -	-----------------
Water circulation	- - -	-----------------
Dominance of land drainage	------- - -	
Dominance of lake water masses	- - -	-----------------
Turbidity levels	- - -	-----------------
Export of detritus	- - -	-----------------
Re-suspension of *in situ* clay	-	-----------------

*NOTE: Dash concentration indicates more concentrated activity.

found in lotic habitat and would not be significantly affected. Those which do inhabit the nearshore areas are capable of movement necessitated by movement of the shoreline. Again, the species most likely to be affected are those which inhabit wetland areas.

The only plant species listed is the American lotus (Nelumbo lutea). This species may be affected as it is a floating aquatic which could be locally displaced by emergent vegetation as water levels decline.

In general, it appears unlikely that the small changes predicted in the water levels of the Great Lakes, due to the maximum-effect diversion scenario, would significantly affect the endangered and threatened species listed. However, if implementation of a scenario appears practicable, it may be desirable to examine more closely the changes which are likely to occur in the specific localities the species in question inhabit. This is particularly true for those species which are typical of wetland areas.

Summary of Impacts on Fish and Wildlife

Attempts to identify and isolate the stress variables affecting populations of fish, wildfowl and wildlife by correlating environmental factors to population changes have generally failed. In some situations, scientists have been able to define coincidences that led to tentative inferences but conclusive evidence was seldom obtained. Therefore, it appears that any attempt to analyze the possible effects of any Great Lakes water level diversion scenario is best directed towards a consideration of habitat alteration and the effects that might have on the higher forms of life.

Within the Great Lakes system, the area most likely to be affected by lake level changes is the shallow water area (nearshore zone) and wetland habitat in particular. The nearshore zone has been arbitrarily defined as the area down to the five fathom (30 foot) depth contour. It approximates the depth to which aquatic plant growth has been recorded in the Great Lakes. Navigation charts were planimetered to calculate the relative areas within this zone for the five Great Lakes (Table 8-12) and maps for each lake (Annex G) show the relative distribution of the zone. Much of the Great Lakes shoreline is barren of plant life, at least down to depths of about 12 feet, where wave and ice actions scour the bottom. Consequently, even within the nearshore zone, the area available for wetland development is very restricted. Based on the International Great Lakes Levels Board Study (1973)[10] inventory of Great Lakes wetlands, less than one-half of one percent of the Great Lakes surface area is emergent wetlands. However, loss of this relatively small habitat base would have serious impacts on the associated wildlife.

8.5.3.3 Water Quality

The water quality evaluation is based on the water quality studies of the International Lake Erie Regulation Study Board (ILERSB). The analysis is separated into two general areas: (1) water quality effects on the whole lake; and, (2) effects in the nearshore zone. The emphasis of the study is placed on the nearshore zone since any water level

Table 8-12
GREAT LAKES NEARSHORE AREAS

Lake	Water Surface (Mi^2)	Area (Mi^2) (SHORE TO 30 ft. WATER CONTOUR)	% (NEARSHORE/ TOTAL)
Superior	31,700	750	2.4
Michigan	22,300	1,888	8.5
Huron	23,000	3,110	13.5
Erie	9,900	1,645	16.6
Ontario	7,600*	992	13.1
TOTAL	94,500	8,385	8.9

* Figure includes area of St. Lawrence River above power dam at Cornwall, Ontario

problems would be most noticeable in shallow waters, where public interaction occurs most often.

The water quality parameters examined by the ILERSB include: hypolimnion volume and associated dissolved oxygen resources; concentrations of nutrients, such as phosphorus; general mid-lake water quality; embayment flushing and pollutant concentrations; nuisance algal growth (Cladophora); nearshore turbidity; and outfall waste dispersion. Different methodologies were employed to evaluate each parameter. Study details, including methodology, can be found in the ILERSB's Water Quality Technical Appendix, An Evaluation of Water Quality Impacts of Proposed Lake Erie Regulation on Lakes Michigan, Huron, and Superior as well as Connecting Channels.

The computed long-term, mean annual water levels of Lake Erie, for the maximum-effect diversion scenario, were similar to the levels generated by one of the plans (SE015S) investigated by the ILERSB. The range of levels and the minimum and maximum levels are similar. (Table 8-13). The water levels of Lakes Superior, Michigan-Huron and Ontario generated by the maximum-effect diversion scenario, are presented in Table 8-14.

Hypolimnion

Lake Erie can be categorized by depths and physical characteristics into three basins; western, central and eastern. Results of the study indicate that a one-foot lowering of Lake Erie could:

(1) decrease central basin hypolimnion volume by as much as 15 percent;

(2) decrease central basin hypolimnion oxygen resources by as much as 15 percent;

(3) not affect natural lake temperatures or the onset of stratification; and,

(4) not affect, significantly, the central basin oxygen depletion rate.

Implementation of the maximum-effect diversion scenario would result in a mean Lake Erie water level decrease approximately 45 percent less than that experienced through implementation of the ILERSB's Plan 25N. Consequently, the loss of hypolimnion oxygen resources and volume would be significantly less severe than under Plan 25N. It has been estimated that the hypolimnion volume reductions from the maximum-effect diversion scenario would be less than four percent. Effects on dissolved oxygen concentrations would be insignificant. Although some loss of fish habitat could occur under the maximum-effect diversion scenario, it seems likely that natural seasonal migration patterns would probably help to reduce detrimental effects which may occur due to hypolimnion reductions. Effects on the hypolimnia of Lake Erie's eastern basin and of Lake Ontario would be even less significant due to their larger volumes and depths.

TABLE 8-13

COMPARISON OF LEVELS OF LAKE ERIE, RESULTING FROM LAKE ERIE REGULATION STUDY PLANS AND GREAT LAKES MAXIMUM-EFFECT DIVERSION SCENARIO (IN FEET)

	Mean	Maximum	Minimum	Range
BOC	570.76	573.60	568.10	5.50
SE015S*	570.53	573.18	568.02	5.16
Plan 25N*	570.17	572.53	567.84	4.69
Diversion	570.48	573.15	568.00	5.15

*Plans for the regulation of Lake Erie which were developed by the International Lake Erie Regulation Study Board.

TABLE 8-14

COMPARISON OF LEVELS OF LAKES SUPERIOR, MICHIGAN-HURON AND ONTARIO RESULTING FROM GREAT LAKES MAXIMUM-EFFECT DIVERSION SCENARIO (IN FEET)

LAKE SUPERIOR	BOC	DIVERSION PLAN
Mean	600.44	600.29
Maximum	601.93	601.83
Minimum	598.69	598.31
Range	3.24	3.52
LAKES MICHIGAN-HURON	**BOC**	**DIVERSION PLAN**
Mean	578.27	577.92
Maximum	581.16	580.59
Minimum	575.46	575.31
Range	5.70	5.28
LAKE ONTARIO	**BOC**	**DIVERSION PLAN**
Mean	244.73	244.55
Maximum	249.47	248.07
Minimum	241.59	240.74
Range	7.88	7.33

BOC - Basis-of-Comparison

The deep upper lakes basins (Lakes Superior, Michigan-Huron) result in much larger hypolimnion volumes compared to those of the lower lakes. Accordingly, a smaller percentage of total hypolimnion volume change could be predicted for a reduction in the upper lakes' levels than would occur in the shallower lower lakes. The maximum mean reduction in lake level for Lake Superior would be 0.1 foot. A reduction of this magnitude would result in a change of only five one-hundreths percent in hypolimnion volume. For Lake Michigan, a maximum monthly mean reduction of 0.57 foot would be equivalent to a hypolimnion reduction of twelve one-hundredths percent. For Lake Huron, the hypolimnion volume reduction would be in the same order of magnitude. These reductions are insignificant when compared to the total lake hypolimnion volume.

There is no oxygen stress during the summer in the hypolimnion areas of Lakes Superior, Huron, or Michigan as compared to what occurs in the western and central basins of Lake Erie. The oxygen depletion rate is dependent upon hypolimnion thickness, among other factors. Therefore, a slight, less than one-tenth percent change in the volumes of the hypolimnia in the upper Great Lakes would not cause any significant reduction in dissolved oxygen concentrations or increase in related biological problems.

Phosphorus

Based upon the ILERSB's investigation, it was determined that a one-foot lowering of Lake Erie would reduce erodible bluff material and the phosphorus associated with these materials by approximately 18 percent. Based upon estimates for 1976, (International Joint Commission, 1978)(12) the 696 tons of available phosphorus from erosion would be reduced by approximately 126 tons. This reduction is about one percent of the available phosphorus discharged from all sources (12,761 tons). The ILERSB's investigation also concluded that mid-lake phosphorus concentrations would not change significantly from the basis-of-comparison. The mean annual water level decrease of 0.28 foot, due to the maximum-effect diversion scenario, would result in decreases substantially less than the one percent reduction expected if Lake Erie's level was lowered by one foot.

Although the greatest positive effect upon Lake Erie eutrophic retardation would result from control of the anthropogenic sources of phosphorus, it is reasonable to assume that any reduction in natural phosphorus input, such as anticipated for the maximum-effect diversion scenario due to reduced erosion, would have a positive effect in achieving that goal.

Similarly, water level changes in the upper Great Lakes would affect the rate of lake aging, due to changes in the amount of nutrient loadings caused by erosion.

While most of the Lake Superior shoreline does not exhibit eutrophication problems due to enrichment from erosion, there are localized problem areas. In Wisconsin, red clay erosion along the shores of Douglas and Bayfield Counties does contribute large amounts of phosphorus to the lake. The Michigan Counties of Houghton, Baraga, and Marquette and some parts of the Keweenaw Peninsula also contribute significant amounts of phosphorus to Lake Superior. The maximum water level of Lake Superior would be lowered by 0.1 foot by implementation of the maximum-effect diversion scenario. This reduction of the maximum lake level should produce a slight beneficial effect as a result of reduced phosphorus loadings due to reduced erosion.

Since the erosion problems on the upper Michigan shorelines of Lake Michigan are minimal, nutrients from shoreline erosion are not an important consideration there. However, nutrients may enter the lake from the shorelines of Schoolcraft and Delta Counties, which are prone to flooding by Lake Michigan.

The shoreline from the Michigan-Wisconsin border to Green Bay, Wisconsin, which is subject to flooding, also has a large portion of agricultural land adjacent to it. For this reason, there may be problems with nutrient additions from the runoff and erosion of farm lands. Although the shoreline of Door County, Wisconsin is not subject to erosion, most of the remainder of the Wisconsin shoreline is agricultural and rich in nutrients, posing the threat of accelerated eutrophication from phosphorus loading caused by shoreline erosion.

The erodible shoreline of Illinois is a mixed urban-industrial area. This area is a small portion of Lake Michigan's shoreline and part of it is well protected from erosion. Little nutrient input from this shoreline is experienced.

The eastern shoreline of Lake Michigan contributes one of the largest sediment loads to the lake. The erosion problem along many miles of this shoreline is such that shore protection and/or beach nourishment programs have been implemented to prevent further damage and property loss. Erosion of bluffs and shorelines increases or decreases as the lake level rises or falls. Based upon available information, a reduction of the water level in Lake Michigan would result in decreased phosphorus loading, depending on seasonal flooding.

The United States shoreline of Lake Huron has few areas subject to serious erosion. Compared with the conditions in Lake Michigan, the amount of soils and nutrients entering the lake are low except during periods of extreme high water. An exception is Sanilac County which contributes an estimated 150 tons of total phosphorus per year. However, the Saginaw River contributes a significant amount of phosphorus to Saginaw Bay and approximately 24 percent of the total phosphorus input to Lake Huron.

Many questions regarding the availability of phosphorus in eroded soils to stimulate algal growth remain to be answered. It is possible that phosphorus from shoreline erosion is mainly found as apatite and generally is not available as an algal nutrient source. Additional research is needed in this area before the significance of eroded soils as a contributor to eutrophication can be defined. With respect to available phosphorus concentrations, implementing the diversion alternative could provide beneficial effects, but it is unlikely that the decrease in available phosphorus (less than 1.0 percent) would be appreciable or of significance.

General Water Quality

Utilizing a conservative parameter (chloride) and an average residence time of 2.4 years for Lake Erie, the ILERSB's study determined that for conditions existing during 1974 and 1976, a one foot lowering of the water level would have amounted to an increase of slightly more than 0.3 milligrams per liter. Other parameters, such as sulfate, carbonate, bicarbonate, dissolved metals, etc., would be affected similarly.

The effect on Lake Ontario is even smaller since the percent reduction in volume resulting from a one foot lowering would be orders of magnitude less than for Lake Erie. This is true because the diversion scenario would have generally less impact on lake levels than the ILERSB's plan; it can safely be anticipated that general water quality on the lower lakes would be insignificantly affected by the diversion scenario.

Chloride values in the upper Great Lakes vary spacially as well as with time. For example, mid-lake observations in Lake Huron ranged from 5.2 to 5.7 mg/l. Lake Michigan measurements at intakes around the lake as well as sampling stations across the lake yielded chloride contents from 4.6 to 17 mg/l. Using 5.6, 7.2 and 1.2 mg/l as the mean chloride concentrations for Lakes Huron, Michigan and Superior respectively, and multiplying these chloride values by the anticipated changes in volume, as a consequence of the diversion scenario's levels, would yield extremely small concentration changes. Such minor changes most likely could not be detected by the instrumentation employed to measure chlorides. Likewise, such small changes are apt to be biologically insignificant.

Embayments

The volume of the embayment, the quantity/quality of water exchanged with the lake, pollutant inputs into the embayment, and the chemical, physical and biological processes within the embayment, govern its water quality.

The physical characteristics of the embayment determine which of the above processes most influences the water quality of that embayment. For the purpose of this study, the latter two factors are assumed constant.

Embayments have been classified into three major categories, for the purpose of this analysis. These are:

(1) embayments that are influenced by tributary inputs;

(2) embayments with a large lake-bay interface (unrestricted); and,

(3) embayments with a small lake-bay interface (restricted).

Lower lake levels due to the maximum-effect diversion scenario would reduce embayment volume. The analysis of embayment pollutant concentrations illustrates that reduced embayment volumes could increase pollutant concentrations.

Since the water quality is predominantly influenced by associated tributary water quality, implementation of the maximum-effect diversion scenario would not affect type (1) embayments. On the other hand, while the volume of type (2) embayments would be reduced, the rapid level balancing response of embayments with a large lake-bay interface (non-restrictive) to daily or even hourly lake level fluctuations, would substantially limit, if not prevent, water quality degradation.

Like the others, type (3) embayments would experience reduced volumes, but in addition would also be subject to increased pollutant concentrations due to lower lake levels. In this case, hydraulic "choking" would prevent adequate lake-bay water exchange resulting in loss of dilution capacity within the bay. Restrictive embayments which are deep (i.e. commercial harbour depth) would not experience any significant impacts due to the maximum-effect diversion scenario. Embayments which are both shallow and restrictive are most likely to experience elevated pollutant concentrations as a result of the maximum-effect diversion scenario.

Turbidity

The ILERSB found a strong relationship between wave energy dissipated at the "toe-of-bluff" and turbidity. When the toe-of-bluff wave energy is altered by lake level changes, some general estimates of turbidity concentrations at different lake levels can be made. These estimates are general because turbidity is affected not only by erosion, where erodible soil is present, but also by anthropogenic sources (pollution inputs), biological production and in-lake chemical precipitation.

The ILERSB identified statistically significant correlations between the toe-of-bluff wave energy and mean monthly turbidity as measured at points on Lake Erie along the Canadian shore of the central basin and along a reach of Ohio shoreline. Based upon model predictions, the data indicate dramatic increases in turbidity as Lake Erie's level approaches 575 feet. It should be emphasized, however, that the highest Lake Erie still-water monthly mean level ever recorded was 573.54 feet in 1973. Short-term higher levels due to wind and barometric pressure effects have been recorded and the dramatic effects alluded to above may only be experienced during periods of such extremes. While the diversion scenarios would be expected to produce reductions in nearshore turbidities, such reductions would be confined to areas of highly erodible shores.

With a reduction in mean lake levels on Lakes Superior, Michigan, Huron and Ontario and a modification in the water level fluctuations, there would be initial changes in sediment deposition, resuspension and dispersal patterns. Alterations in the amount and areal extent of shoreline erosion probably would account for the majority of the impacts regarding turbidity. Utilizing the equations employed in the International Lake Erie Regulation Study, decreases in turbidity of up to five percent in nearshore areas can be anticipated from implementation of the maximum-effect diversion scenario.

Cladophora

The excessive growth of the alga, Cladophora sp., is a continuing aesthetic and nuisance problem in Lakes Erie and Ontario. The primary cause of these excessive growths is over-enrichment with nutrients from pollution and not from natural or cultural lake level fluctuations. Other basic growth requirements of Cladophora include a compatible substrate and light availability, which are influenced by varying lake levels. Lowering lake levels may affect the substrate area available for Cladophora growth, depending upon the specific reach of shoreline being considered. At the same time, decreased turbidities would result in greater lake clarity and consequently increased light penetration and availability. The increased light intensity can stimulate Cladophora production over and above that attributable to increased substrate. The ILERSB did not consider light availability in its Cladophora assessment because of insufficient data. However, based upon increased substrate alone, it was calculated that lowering Lake Erie water levels by one foot would cause a mean increase in Cladophora production of approximately two percent. Within individual years there would be decreases in production, but increases of up to 14 percent were predicted for some years.

An analysis of the Cladophora production in the Lake Erie Bass Islands region, where growth is most prolific, was calculated by the ILERSB. This study indicates that the changes in water levels for Lake Erie as a result of the maximum-effect diversion scenario would serve to increase mean annual Cladophora production in the order of 1.4 percent. Maximum annual increases and decreases of 7.1 percent and 0.7 percent respectively have been calculated as well for the island area. The impacts of the maximum-effect diversion scenario on Lake Erie (reduction of about five inches) can be expected to produce lake-wide increases in Cladophora growth substantially less than the average calculated for a one-foot decline in water level.

Data for Lake Ontario are unavailable; however, it is anticipated that any level reduction in Lake Ontario would only tend to shift Cladophora production further from shore. It is likely, however, that nutrients will become the limiting factor to Cladophora production in the future. In fact, this is the goal of the U.S.-Canada pollution control programs currently underway. If nutrients become limiting, Cladophora production in the lower lakes would decrease irrespective of lake levels. It appears, therefore, that the diversion effects on the lower lakes with respect to algae production would be minimal and insignificant.

Because Lake Superior is quite oligotrophic and cold, it is not susceptible to invasion by Cladophora. Any water level lowering would probably add to the Cladophora problem along the western shore of Lake Michigan. By virtue of its temperature regime and nutrient concentrations, the Green Bay-Sturgeon Bay region is a likely area for increased Cladophora growth resulting from lowered lake levels which would expose more substrate. However, in the final analyses, the changes in Cladophora production in the upper Great Lakes would be minimal as a consequence of the exposure and subsequent loss of currently suitable habitat if the maximum-effect diversion scenario was implemented.

Waste Outfalls

Reduced water levels may have an adverse effect in that a smaller volume of water in the nearshore zone would be available to dilute wastes from industrial and municipal outfalls.

Initial dilution, which is important in all outfall systems, is a function of several variables, including the depth of discharge. Insignificant decreases in initial dilution would occur at the 10-foot and 20-foot depths. For outfalls at the surface (e.g., storm sewers), effects would be limited to the aesthetic drawbacks of outfall head exposure.

The International Lake Erie Regulation Study concluded that a one-foot lowering of lake level, independent of location, would have a minimal effect on the existing industrial and municipal outfalls in the lower lakes. No lake level decreases greater than 0.6 foot are anticipated due to the maximum-effect diversion scenario.

On a volume basis, changes in lake levels of the magnitude predicted will result in very minor reductions in the dilution of discharges from outfalls to Lake Superior while Lakes Huron and Michigan would be reduced by less than one-tenth percent. In conclusion, the maximum-effect diversion scenario would not affect existing outfall waste dispersion patterns.

Summary

Implementation of the maximum-effect diversion scenario would not significantly affect the lower lakes water quality. With respect to turbidity, phosphorus, Cladophora production, outfall dilution and general water quality, the maximum-effect diversion scenario would produce only insignificant environmental changes. In some instances (turbidity and phosphorus), a small positive benefit would accrue. However, with respect to shallow, restrictive embayments some dilution capacity would be lost. This could exacerbate potential problems related to accidental spills or discharge bypasses due to equipment malfunction or cleaning. Although the maximum-effect diversion scenario would decrease the volumes and oxygen resources of all Great Lakes hypolimnia, no significant acceleration of hypolimnion oxygen depletion rates would occur.

The impacts of the maximum-effect diversion scenario on the water quality of Lakes Superior, Huron and Michigan and their connecting channels would be slight and/or short-lived. Levels of turbidity, Cladophora, nutrients from erosion, sediment transport and waste dispersion would not change appreciably. Any negative effects probably would occur in shallow bays with restricted openings to the lake. In such embayments, reduced water levels would increase stagnation as well as the potential for damage if pollutants were released within the bay.

8.5.3.4 Environmental Effects on Diversion Areas

Lake Michigan Diversion at Chicago[19]

Because the amount of water diverted through the Lake Michigan Diversion system at Chicago could be significantly increased by the maximum-effect diversion scenario, it is necessary to consider the environmental consequences of such a diversion increase on this waterway system as well. The increased diversion would affect the environmental conditions of the Illinois Waterway in many ways. The major concerns of immediate consequence are: water quality, sediment conditions and the biota. Both beneficial and adverse conditions would occur with an increased diversion.

Increases in dissolved oxygen content (DO), reduction in ammonia, dilution of other toxic substances and temperature reductions will occur in the Canal Reach and Upper Valley Reach of the Illinois Waterway, with concurrent benefits to aquatic life. Adverse effects would include scouring in the Canal Reach resulting in downstream movement of polluted canal bottom deposits, and possible reduction in DO levels in the LaGrange Pool (River Mile 80 to River Mile 158) during low flow periods.

Diversion-induced increases in water velocity would contribute to increased turbidity and possible increases in sedimentation in backwater lakes.

The greatest change would probably occur to the waterway's biota. Increased diversion would increase the availability of deepwater habitat which could benefit populations of muskrats and some fish. Adversely, it could reduce the life expectancy of bottomland forest with a consequent habitat reduction for terrestrial vertebrates; decrease the area of aquatic vegetation and associated fauna; eliminate mudflats for moist soil plants which provide shorebird habitat and food for waterfowl and decrease the existing marshes and associated spawning grounds. New shallow areas created by higher stages would provide new potential habitat for semi-emergent and floating plant communities and furnish a favorable environment until the existing sedimentation trend would again degrade the new habitat. Increased diversion would also increase the Lake Michigan type plankton communities in the waterway.

Because increased diversions from Lake Michigan at Chicago would be intermittent in nature, all benefits are temporary and periodic. Conversely, any detriments caused thereby may persist long after increased diversion is curtailed.

Long Lac/Ogoki Diversions

It is not possible to directly identify the effects that the maximum-effect diversion scenario would have on the aquatic resources of the Long Lac/Ogoki Diversions. There is, however, considerable published material from other studies in North America and Europe that has provided some guidance in identifying possible areas of concern.

The reservoirs of the system, Lake Nipigon, Long Lake and Ogoki would not be affected by the diversion scenarios. They would continue to be operated within the limits set by the province of Ontario.

The present method of operating the diversions has flattened out the natural downstream hydrographs by withholding spring flood waters in the reservoirs for release during low water periods. This may have had effects on: the temperature regime of the rivers; the siltation of potential spawning sites; the timing of freeze-up and ice break-up in the rivers; the distribution and abundance of benthic organisms and the behaviour, distribution and abundance of certain species of fish. It does not appear that even the maximum-effect diversion scenario would alleviate to any significant degree the disturbances created by the operational mode now in effect. However, the Long Lac/Ogoki Diversions systems have experienced re-routing into their former drainage patterns for extended periods during 1952 and 1974. In order to help relieve prevailing high water levels on the Great Lakes, diversion waters were routed northward or stored in Lake Nipigon during those periods.

In the northward-flowing rivers, the effects of the present diversion practices may have been buffered somewhat by the inflows from tributary streams a few miles downstream of the control structures. The existing diversion system probably produced many of the downstream effects noted above, as well as effects on delta formation at the mouths of the tributary streams and the invasion of terrestrial riparian vegetation into the old riverbed.

Any of the diversion scenarios would initially disrupt the terrestrial ecosystems that are now established immediately below the control structures. The arhythmic nature of any diversion scenario would further disrupt the aquatic ecosystems on both sides of the Ogoki and Long Lake reservoirs.

Welland Canal

The Welland Canal is a deep draft, man-made waterway joining Lake Erie with Lake Ontario across the Niagara Peninsula in Ontario, Canada. In this context, the "environment" for the Welland Canal is a contrived feature which was never intended to stabilize completely. Since the early days of the first Welland Canal, the steady pressure of increasing traffic has brought about successive extensions and enlargements to the navigation facilities and hydropower developments to meet the expanding requirements of trade and population. Recent diversions have approached an average 9,000 cfs. Maximum discharge capacity through the canal associated facilities are estimated to be no more than 10,000 cfs. Therefore, any additional diversions through this waterway would be relatively minor and additional impacts to the environment - over and above those now experienced - would be expected to be correspondingly minor as well. The canal has not significantly affected land drainage, as most local streams and rivers are diverted parallel to or beneath the canal. Most of the water withdrawn from the canal for municipal and industrial usages is returned to the canal under guidelines prescribed by the Ontario Ministry of Environment.

New York State Barge Canal System

The effects of the New York State Barge Canal are very small and are generally ignored in studies on Great Lakes water levels. Diversion flows in recent years are estimated to average about 700 cfs annually which is about 0.3 percent of the Lake Erie outflow through the Niagara River. Since this diversion is made from well below the head of the Niagara River which is the major hydraulic outflow from Lake Erie, it does not affect Lake Erie levels.

Alterations in the water levels of this diversion system would be extremely minor as a result of implementation of the maximum-effect diversion scenario. As a consequence, environmental impacts would be largely immeasurable and expected to be of little significance.

8.5.4 Social Effects

The following assessment of possible social impacts is based on information from the International Lake Erie Regulation Study Board, (1981)(13) and upon the application of those determinations to other areas of the Great Lakes. The social impact assessments are mainly qualitative, rather than quantitative. That Board's report segments on Recreational Boating Evaluation and Water Quality Analysis were used as an aid in evaluation techniques.

8.5.4.1 Population Growth

The rate of population growth in the Great Lakes basin is decreasing, especially in the major urban centers of the United States. Experts point to the U.S. region's declining economy as the major reason for a reduction in the rate of population growth. The lower lake levels that would result from the maximum-effect diversion scenario would have a negligible direct effect on the population dynamics of the basin. However, since lower levels would have negative impacts on commercial navigation and electrical energy production costs, employment opportunities could also be affected adversely which could influence population movement out of the basin.

8.5.4.2 Recreation

Hunting

Lower lake levels could cause a reduction in the acreage of hemi-marsh habitat. The hemi-marsh is the optimum condition for wildlife species diversity. Water levels below the historical long-term mean encourage the predominance of sedge/meadow vegetation. This condition favors upland game species, such as white-tailed deer and cottontail rabbits, at the expense of wetland-dependent wildlife and waterfowl; i.e., muskrat, ducks and geese. Should wetland-dependent game species be replaced by upland species, a concomitant shift in the area's hunting resources could occur.

Waterbirds including ducks, geese and shorebirds, require wetland for breeding, feeding, rearing and staging areas. Saginaw Bay, Lake St. Clair and the western end of Lake Erie, all near major population centers, are well known concentration areas for migrating waterfowl. The migrants stop at these locations to rest and feed on their yearly travels. Tremendous numbers of birds congregate due to the protected environment and availability of food. Key foods are of the submergent and emergent vegetation types. Any water level changes that would result in the shift of submergent/emergent vegetation to sedge/meadow vegetation, with the subsequent decline of the area as a waterfowl habitat, would adversely affect recreation. Not only would hunting interests be affected, but such non-consumptive recreational interests as bird watching and photography could be affected as well.

Fishing

Many important gamefish, which include largemouth bass, northern pike and muskellunge, require wetlands for survival. Some species are even dependent on specialized conditions. For example, northern pike (Esox lucius) are dependent on early spring flooding of sedge or shrub meadows for spawning. Adults feed and rest in floating, submerged and emergent vegetation throughout the warm months. Juvenile fish rely on heavy vegetation for cover and also feed on the invertebrate populations that inhabit the submerged vegetation. Also, high water is important to facilitate the interchange between the lake and the wetland, thus permitting fish spawning (e.g., northern pike) as well as the wetland rearing of forage fish (Jaworski et al, 1979).[15]

The importance of the Great Lakes to recreation fishing is well documented. Sport fishing has just recently begun to make a comeback from the destruction inflicted on the sport due to pollution and the lamprey eel. Precautions should be taken not to impede the progress of this recovery. Lake level changes that reduce the area of wetland habitat may be harmful to sport fishing. However, there have not been enough studies on the subject of impacts to fish caused by water level changes to make a quantitative assessment of the impacts. Should a diversion scenario be selected for implementation, site specific studies would be necessary.

Beach Recreation/Boating Recreation

Implementation of the maximum-effect diversion scenario would generally be beneficial to beach recreation by exposing more beach area. The amount of new beach area exposed would vary locally and depend upon: 1) the magnitude of water level lowering and 2) the localized bottom contours; i.e., degree of slope. The greatest impacts on recreational boating would occur in the nearshore area, the approach channels, harbors and bays. Recreational boating channels that are presently at or approaching the minimum depth for boat passage may need dredging should a diversion scenario be implemented. Also, some docking facilities may be rendered unusable. The methodology used to evaluate the changes which would occur in these areas under the maximum-effect diversion scenario, and the results of these evaluations, have been presented earlier. (See Sections 8.3.2.1 and 8.5.2).

8.5.4.3 Water Quality

Impacts of the maximum-effect diversion scenario on water quality and water use as related to population dynamics would be at most slight and/or short-lived. The most noticeable negative effects could occur in shallow bays with restricted openings to the main lake. In such embayments, reduced water levels could increase stagnation as well as the potential for damage if pollutants were released within the bay. Extended periods of such conditions would certainly influence the human use of an area so impacted. Water quality might realize slight improvements from a reduction of non-point sediment loading with the lessening of shoreline erosion. More details on this topic were presented earlier in Section 8.5.3.3.

8.5.4.4 Shore Erosion and Coastal Flooding

Shoreline erosion and coastal inundation processes are sensitive to changes in lake water levels. Since the maximum-effect diversion scenario would serve to reduce the maximum mean lake levels and decrease the range of mean water levels, positive socio-economic impacts would result from these modifications. The most obvious effects from lowered water levels would be a reduction in coastal property damages, monetary loss and human stress. Other benefits realized would be a lessening of non-point sediment loading to the lakes which, in turn, would help to enhance nearshore water quality by reducing as a result of decreased erosion, turbidity and chemical input received from the soils being eroded. Aesthetic values would be renewed by diminishing the visual losses which result from eroded shorelines, submerged beaches and the emplacement of protective structures. A supplementary benefit might be realized from a reduction in public expenditures for coastal hazards management since there would be a concomitant decrease in government effort to aid in flood and erosion prevention, mitigation or disaster recovery.

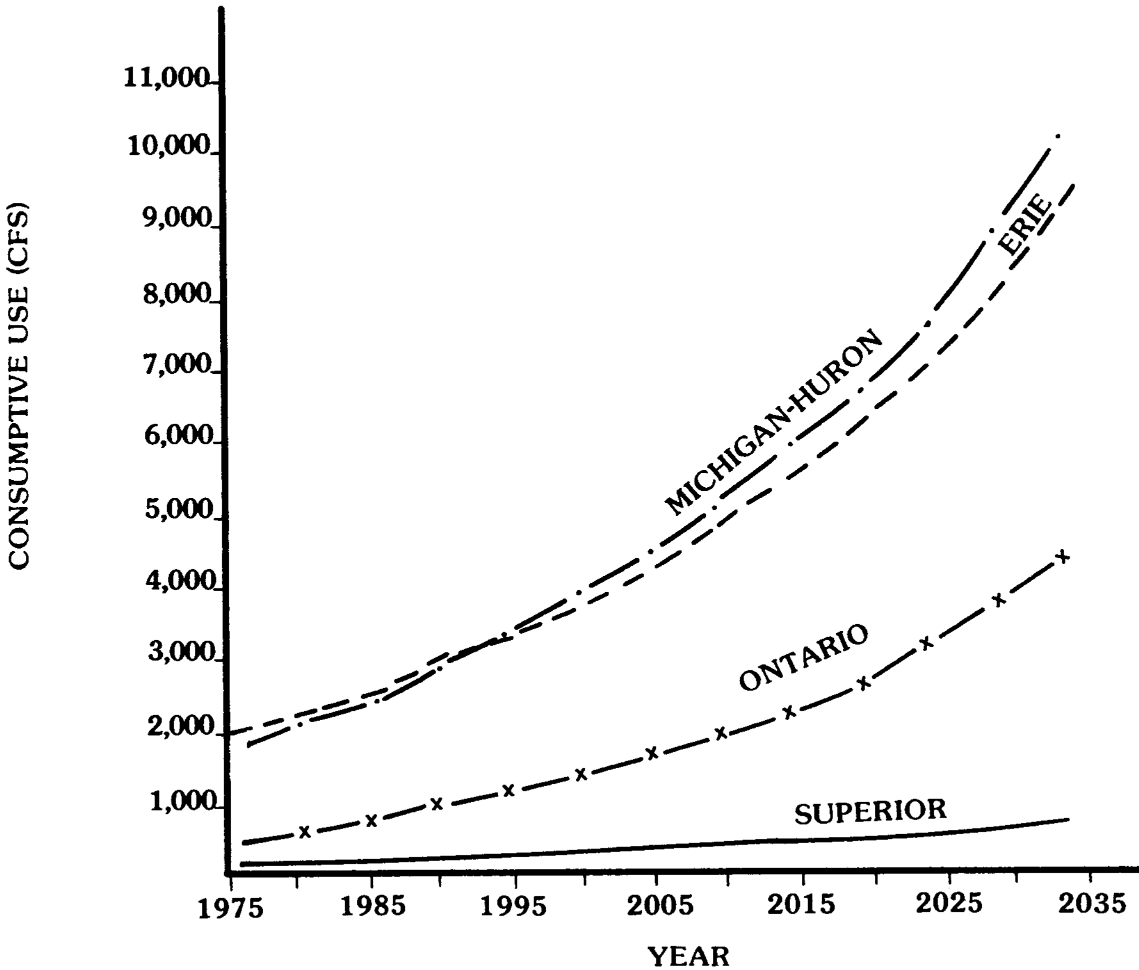
8.5.4.5 Summary

Implementation of the maximum-effect diversion scenario should not produce any significant social effects. Population growth trends would not be directly affected; however, adverse impacts on waterborne commerce and power production could induce population shifts. Hunting pressure may shift from wetland-dependent game to upland species. Non-consumptive wildlife-related recreation could experience a slight decline. Beach use would likely benefit from more exposed shoreline, but recreational boating could either benefit from a stabilization of water level extremes or suffer adversely from a reduced water depth in shallow areas such as approach channels, marinas and embayments. Adverse impacts to the sport fishery in specific nearshore areas could also be incurred by lower water levels. Water quality could be influenced either adversely from increased degrees of contamination in restricted bays as a result of lowered water levels or beneficially from the reduction of sediment loading as a result of less shore erosion. Coastal property owners could benefit as a result of decreased erosion-induced damages. The perceived benefits or disbenefits would be relatively modest as the indicated water level reductions produced by the maximum-effect diversion scenario are relatively minor.

8.6 Evaluation of Consumptive Uses

Section 6 of this report describes in detail the current consumptive uses of water within the Great Lakes basin. The section also outlines the future losses which could occur if the present trends (most likely projection - MLP) continue and certain public laws are fully implemented. Coupled with these projections are high and low estimates about the MLP. These projections are presented in Figures 8-2 to 8-4. The MLPs are summarized on Figure 8-2 which shows that there would be very little effect on the volume of Lake Superior, as a result of increasing consumptive uses, from about 240 cfs in 1975 to 740 cfs by the year 2035. Over the same period, consumptive uses from the Lake Erie basin are expected to increase from about 2,200 cfs to approximately 9,500 cfs. The ratio of increase on both of these lake basins is about equal; i.e., four to one. However, the impact on levels and flows will be more pronounced for Lake Erie, because of its size and the fact it will be experiencing the impact of all upstream losses. The ratio of increase on the other two lakes (Lakes Michigan-Huron, five to one and Lake Ontario, nine to one) are somewhat higher than those shown for Lakes Superior and Erie.

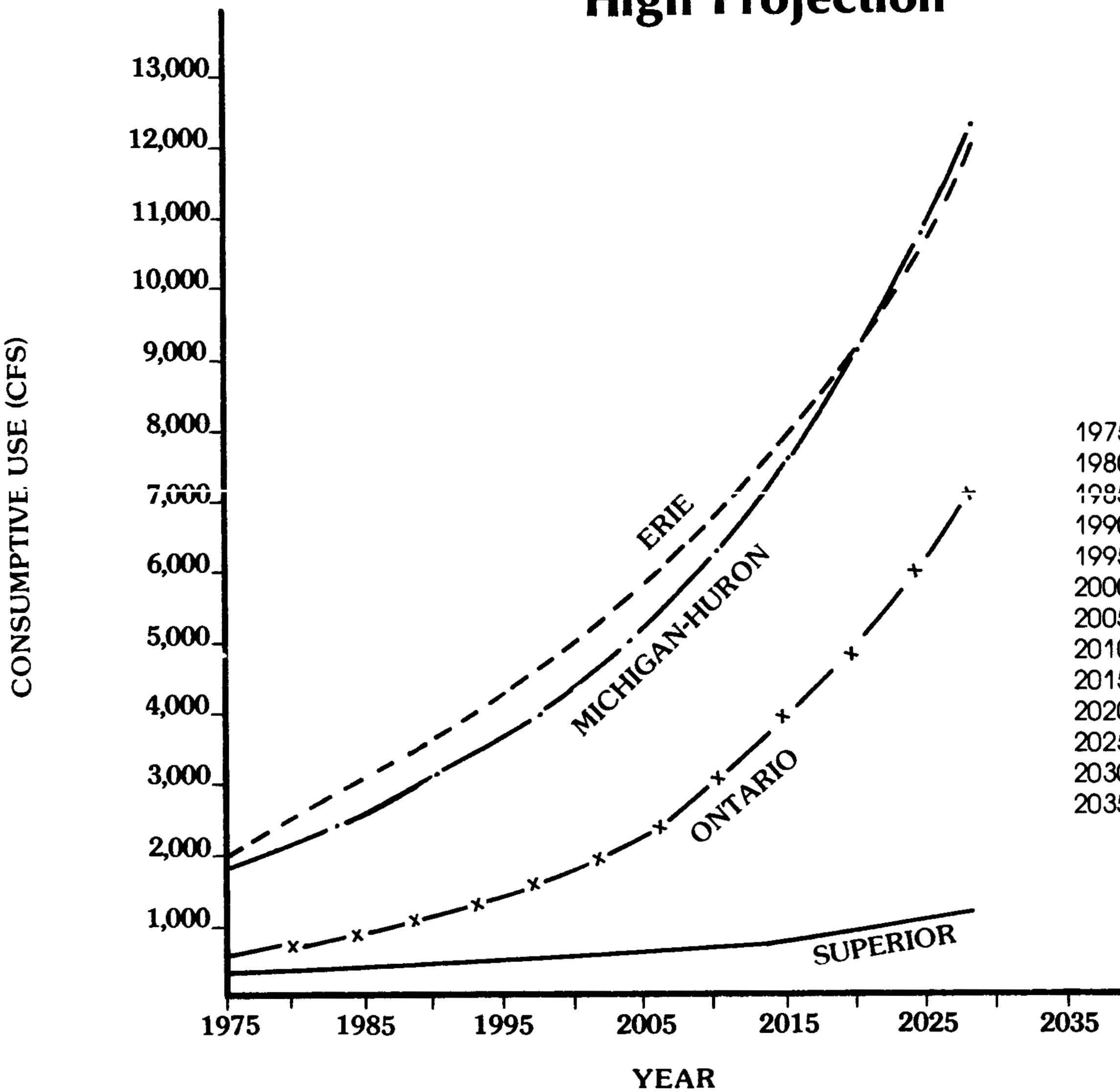
Projected Range of Consumptive Water Uses
Most Likely Projection (MLP)



	SUP	M-H	ER	ONT	TOTAL
1975-	240	1960	2210	530	4940
1980-	260	2290	2420	640	5610
1985-	290	2620	2690	770	6380
1990-	320	3020	3100	940	7390
1995-	350	3560	3520	1130	8560
2000-	380	4140	4000	1370	9890
2005-	420	4670	4550	1620	11300
2010-	460	5360	5150	1920	12900
2015-	500	6150	5850	2280	14800
2020-	550	7020	6580	2750	16900
2025-	600	8050	7470	3280	19400
2030-	670	9190	8380	3840	22100
2035-	740	10550	9490	4570	25400

Figure 8-2

Projected Range of Consumptive Water Uses
High Projection



	SUP	M-H	ER	ONT	TOTAL
1975-	240	1960	2210	530	4940
1980-	270	2370	2700	740	6080
1985-	310	2790	3220	930	7250
1990-	350	3290	3840	1170	8650
1995-	400	3870	4490	1440	10200
2000-	440	4500	5180	1750	11900
2005-	500	5210	5970	2180	13900
2010-	580	6090	6850	2690	16200
2015-	660	7100	7820	3280	18900
2020-	790	8430	8990	4270	22500
2025-	930	9960	10300	5390	26600
2030-	1080	11650	11700	6600	31100
2035-	1230	13820	13500	8000	36500

Figure 8-3

Projected Range of Consumptive Water Uses
Low Projection

	SUP	M-H	ER	ONT	TOTAL
1975-	240	1960	2210	530	4940
1980-	260	2270	2290	620	5440
1985-	290	2540	2390	730	5950
1990-	320	2890	2510	850	6570
1995-	350	3280	2680	980	7290
2000-	380	3670	2870	1120	8040
2005-	410	3980	3180	1290	8860
2010-	450	4320	3540	1470	9780
2015-	490	4700	3900	1680	10800
2020-	550	5180	4270	1980	12000
2025-	600	5690	4670	2310	13300
2030-	650	6260	5120	2670	14700
2035-	700	6930	5590	3060	16300

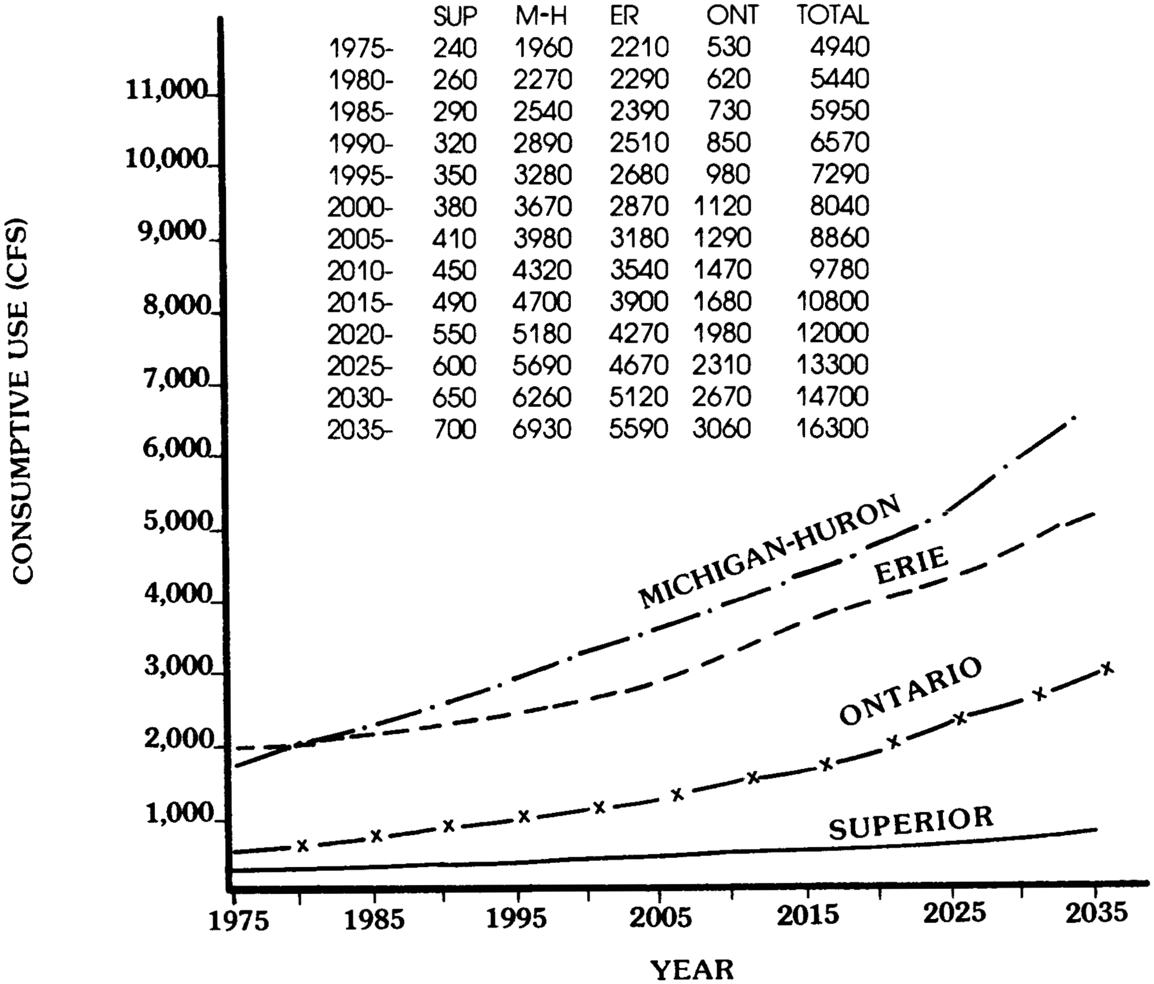


Figure 8-4

8.6.1 Hydrologic Effects

In order to obtain an indication of the hydrologic effects of projected consumptive uses (as shown on Figure 8-2 to 8-4) on Great Lakes levels and outflows, the Board employed three methods for comparision purposes.

Method 1 assumed that the historical water supply received during the period 1916-1976 would be repeated in the same sequence and magnitude over the next 60 years. To determine the hydrologic effect on levels and outflows, the yearly projected consumptive uses were subtracted from the yearly historical water supply. The resultant reduced water supply was routed through the lake system.

Method 2 used the same historical water supply record as Method 1. However, to determine the hydrologic impact, the consumptive uses at each 10 year increment were subtracted from that total water supply record. The resultant reduced water supply was routed through the lake system to obtain six comparisons on the historical water supply period.

Method 3 reflects the fact that the water supply (both in sequence and magnitude) for the next 60 years is unknown, but assumes that the average water supply for that 60-year period would be the same as the historic average (1916-1976). To determine the hydrologic impact, the projected consumptive uses as evaluated under both Method 1 and 2 were each subtracted from that average water supply and each routed through the system to obtain two additional comparisons.

The results of applying each of these techniques with the MLP are summarized in Tables 8-15 and 8-16 and the impact on the mean level has been plotted on Figures 8-5 and 8-6 as a deviation from the basis-of-comparison.

The results show that under all three methods (except for Lake Ontario under Method 3) there would be a general lowering of lake levels throughout the system. Methods 2 and 3 demonstrate (for the upper lakes) that there would be only a slight impact on the range of levels. However, Lake Ontario presents an anomaly to that situation. On that lake the range would be increased by approximately 1.25 feet under Method 1 and by 5.5 feet under Method 2 when the projected increases in consumptive uses are applied to the historical water supply period. This is due to the fact that under Regulation Plan 1958-D (the current regulation plan for that lake) fixed minimum flows are employed. Hence, under the reduced water supply situation and the fixed minimum flow, more storage would be extracted from the lake than under the condition for which Plan 1958-D was designed. This is in contrast to the unregulated lakes (Lakes Michigan-Huron and Erie) in which lake outflow reflects the water supply situation (as the level is reduced, so is the outflow). Little impact is shown on Lake Superior (a regulated lake which also employs a fixed minimum flow), because of its size and the minimal projected increase in consumptive use over the next 60 years.

TABLE 8-15
EVALUATION OF PROJECTED CONSUMPTIVE USES USING ACTUAL CONDITIONS FOR PERIOD 1916-1976
LEVELS AND FLOWS
MLP

	Basis-of-Comparison (1916-1976)		Method 1		Method 2-10		Method 2-20		Method 2-30		Method 2-40		Method 2-50		Method 2-60	
LAKE SUPERIOR	Feet	Tcfs	Feet	Tcfs	Feet	Tcfs	Feet	Tcfs	Feet	Tcfs	Feet	Tcfs	Feet	Tcfs	Feet	Tcfs
Mean	600.39	77	600.30	77	600.36	77	600.33	77	600.30	77	600.26	77	600.20	77	600.13	77
Max.	601.65	120	601.60	120	601.65	120	601.64	120	601.61	120	601.60	120	601.51	119	601.49	118
Min.	598.67	55	598.65	55	598.62	55	598.60	55	598.56	55	598.52	55	598.48	55	598.40	55
Range	2.98	65	2.95	65	3.03	65	3.04	65	3.05	65	3.08	65	3.03	64	3.09	63
LAKES MICHIGAN-HURON																
Mean	578.17	184	577.90	181	578.09	183	578.01	182	577.91	181	577.80	179	577.63	178	577.42	175
Max.	581.13	232	580.91	230	581.06	231	580.97	230	580.88	228	580.74	226	580.57	224	580.35	221
Min.	575.47	112	575.01	110	575.38	111	575.29	110	575.19	109	575.07	107	574.89	105	574.66	103
Range	5.66	120	5.90	120	5.68	120	5.68	120	5.69	119	5.67	119	5.68	119	5.69	118
LAKE ERIE																
Mean	570.73	207	570.44	201	570.65	205	570.57	203	570.47	201	570.34	199	570.18	195	569.96	191
Max.	573.59	270	572.94	257	573.52	269	573.42	266	573.34	264	573.20	261	573.03	257	572.81	252
Min.	568.09	152	567.75	148	568.01	150	567.92	148	567.81	146	567.68	144	567.49	140	567.25	136
Range	5.50	118	5.19	109	5.51	119	5.50	118	5.53	118	5.52	117	5.54	117	5.56	116
LAKE ONTARIO																
Mean	244.74	241	244.23	234	244.67	240	244.56	237	244.38	235	244.13	232	243.58	227	242.30	222
Max.	249.42	310	247.16	310	248.89	310	248.39	310	248.10	310	247.77	310	247.36	310	247.02	310
Min.	241.58	188	238.04	188	240.99	188	240.40	188	239.71	188	238.74	188	237.19	188	233.50	188
Range	7.84	122	9.12	122	7.90	122	7.99	122	8.39	122	9.03	122	10.17	122	13.52	122

TABLE 8-16
EVALUATION OF PROJECTED CONSUMPTIVE USES USING AVERAGE CONDITIONS FOR PERIOD 1916-1976
LEVELS AND FLOWS
MLP

	Basis-of-Comparison (1916-1976)		Method 3-1		Method 3-2-10		Method 3-2-20		Method 3-2-30		Method 3-2-40		Method 3-2-50		Method 3-2-60	
LAKE SUPERIOR	Feet	Tcfs	Feet	Tcfs	Feet	Tcfs	Feet	Tcfs	Feet	Tcfs	Feet	Tcfs	Feet	Tcfs	Feet	Tcfs
Mean	600.45	77	600.36	77	600.42	77	600.39	77	600.36	77	600.32	77	600.26	77	600.18	77
LAKES MICHIGAN-HURON																
Mean	578.19	184	577.93	181	578.12	183	578.04	182	577.94	181	577.83	180	577.67	178	577.46	175
LAKE ERIE																
Mean	570.75	207	570.47	201	570.68	205	570.59	204	570.50	201	570.37	199	570.21	195	569.99	191
LAKE ONTARIO																
Mean	244.50	242	244.65	234	244.50	240	244.49	238	244.50	235	244.55	232	244.98	228	245.64	222

Methods 1 and 2

DEVIATION of MEAN LEVEL from BASIS-of-COMPARISON

(Using actual water supply conditions for period 1916-76)

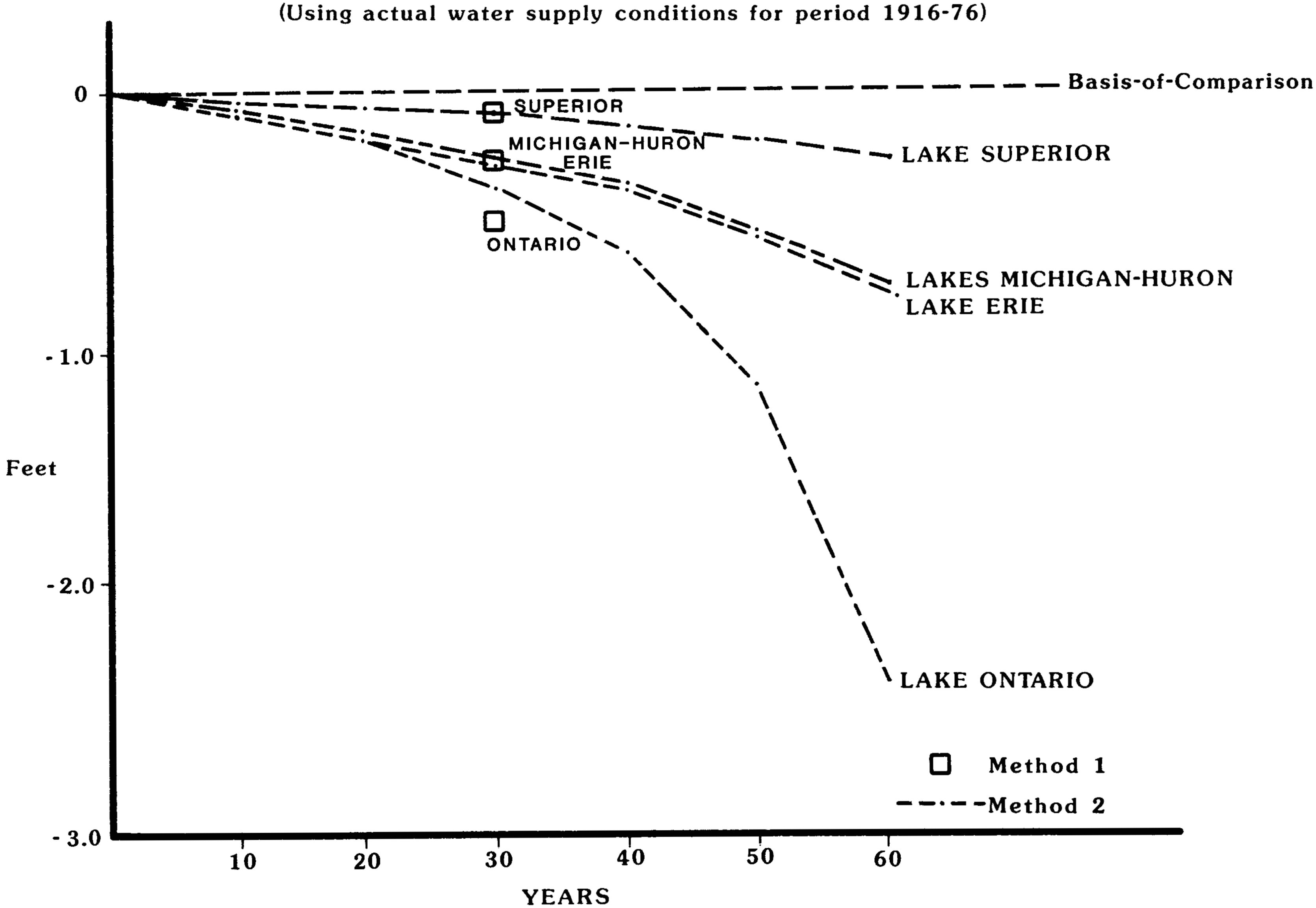


Figure 8-5

Method 3

DEVIATION OF MEAN WATER LEVEL FROM BASIS-OF-COMPARISON
(USING AVERAGE WATER SUPPLY OVER THE PERIOD 1916-1976)

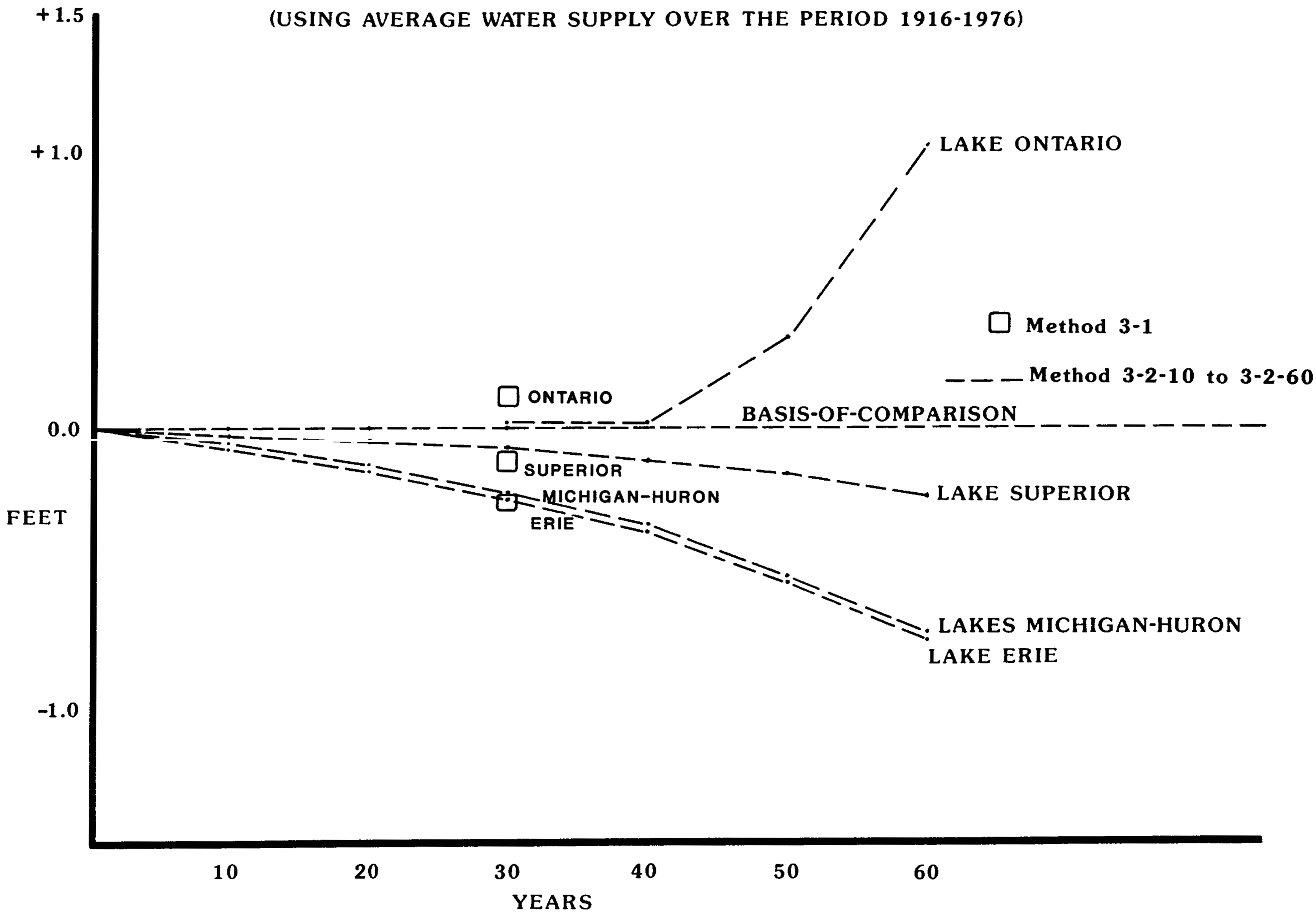


Figure 8-6

Method 3 shows the same apparent effect on the mean levels that is shown by Method 2 for Lakes Superior, Michigan-Huron and Erie. However, Lake Ontario again presents an anomaly. In this case the mean levels would rise with time. This is due to the effect of employing the constant average water supply coupled with the increasing consumptive use on Regulation Plan 1958-D. In effect, the reduced water supply would cause Plan 1958-D to prevent the lake from dropping too low by reducing the outflow and placing water into storage equal to the reduction in water supply. It would appear, from an analysis of the result of Methods 2 and 3, that marked revisions to Plan 1958-D, as designed, would be required prior to the year 2000, if the reduction in water supply occurs (as projected by the MLP) and the criteria for regulation of Lake Ontario are to be satisfied to the same degree as at present.

8.6.2 Qualitative Economic Analysis of Consumptive Uses

The hydrologic impacts of the consumptive uses MLP to the year 2035 are shown in Tables 8-15 and 8-16. The tables indicate that on all lakes, except Lake Ontario, the range of levels would remain approximately the same. However, their regimes would be lowered and mean levels reduced from 0.25 to 0.75 of a foot. Similar results are produced whether a particular hydrologic sequence is employed or average conditions are assumed.

To obtain an indication of the qualitative economic impacts of the lowering shown on Tables 8-15 and 8-16, a comparison can be made with the impacts produced by the lowerings which would occur through the management of existing diversions (Table 8-3). Scenario 9 (the maximum-effect diversion scenario) shows a lowering of the mean levels on Lakes Superior and Michigan-Huron of 0.15 foot and 0.35 foot respectively. This lowering is comparable to that which is produced by the consumptive use MLP in about 40 years, Tables 8-15 and 8-16 (2-40; 3-40). Table 8-6 indicates that the maximum-effect diversion scenario (Scenario 9) would produce an average annual benefit to the coastal zone interest of about six million dollars. Since similar lowering of levels results from consumptive use projections, benefits to coastal zone interests of the same order of magnitude could be expected in about 40 years and substantially more by the year 2035.

The major hydro-power facilities within the Great Lakes system are located on the Niagara and St. Lawrence Rivers. Any reduction in available water upstream of these points would be felt fully by these plants. As indicated by Table 8-6, a reduction in water supply of 5,500 cfs on trigger (average 2,750 cfs) under Scenario 7 would result in an annual loss of $41.4 million to the power interests. Although it is not shown on Table 8-6, $32.0 million of the loss would apply to the Niagara River and $9.4 million at the St. Lawrence River. Using this analogy, a reduction in water supply due to consumptive uses MLP could result in annual losses to power of an estimated $145 million in 40 years and $205 million by the year 2035.

Comparison of the minimum levels (Tables 8-3 and 8-15), as an indicator of the impact on navigation, shows that the levels of all lakes (except Lake Superior) would be lowered more by projected consumptive uses than by the maximum-effect diversion scenario. This would indicate that the losses to navigation will be correspondingly greater. From the data available it can be concluded that navigation losses due to the consumptive uses MLP would be greater than the $13.8 million shown for the maximum-effect diversion scenario.

In summary, the consumptive uses MLP would result in benefits to coastal zone interests, but losses to power and navigation. These losses would far exceed those shown for the maximum-effect diversion scenario. However, it should be realized that these economic losses to the navigation and power interests on the Great Lakes would be tempered in various degrees by the benefits derived by the consumptive users of the water. Water has an economic value. The consumptive uses examined in this study represent a loss of water to the Great Lakes system and hence a redistribution of its inherent benefits from Great Lakes user interests to consumer interests. However, determination of the economic value of the water to municipal, rural-domestic, manufacturing, mining, rural-stock, and irrigation sectors would be an extremely complex undertaking and beyond the resources available to the Board.

8.7 Summary

The Board developed 43 diversion management scenarios to address the issues raised by the Reference from the governments and included in the IJC Directive to the Board, and hydrologically evaluated in detail the impacts on Great Lakes levels and flows for 13 of these scenarios. In addition to the hydrologic evaluation, the Board evaluated 10 scenarios economically and one environmentally.

The hydrologic evaluation shows that it is possible, through modification of the diversion rates, to affect the extreme levels of the Great Lakes. However, the analysis also shows that a residual effect would be felt on lake levels after a particular diversion has been returned to its pre-modification rate. Due to lag within the Great Lakes system the residual effect transcends the high lake level period and in some cases impacts on the extreme low level conditions.

A comparison of the basis-of-comparison conditions used in this study with the actual long-term Long Lac/Ogoki and the Welland Canal Diversions indicate that these diversions are greater than the basis-of-comparison rates. The net effects of these increases on the regime of levels was small, within a few hundredths of a foot, with the exception of Lake Erie which was lowered about 0.10 foot.

The economic evaluations provided by the International Lake Erie Regulation Study Board show: (a) that the maximum-effect diversion scenario would result in an overall loss to users of the system. In general, benefits of as much as $6 million would accrue to coastal zone interests with losses to the navigation and power interests of as much as $14 million and $61 million respectively; (b) that the actual increase in diversion rates for Long Lac/Ogoki and Welland Canal over the adopted basis-of-comparison rates indicates that the increased inflow from Long Lac/Ogoki would result in losses to the coastal zone interests of $0.7 million within the system, but would produce benefits to navigation and power interests of $1.8 and $10.2 million, respectively. Increasing the Welland Canal flow would provide losses to navigation of $2.0 million, but benefits to the coastal zone and power interests of $1.0 and $1.5 million respectively; in combination, the two effects produce an overall benefit in the order of $12 million.

Implementation of the maximum-effect diversion scenario should not produce significant environmental or social effects. Overall, environmental effects on the Great Lakes system would be similar to those experienced as a result of existing water level fluctuations. However, minor detriments and/or benefits could be expected in some localized areas on the Great Lakes as a result of long-term lake level reductions.

The evaluation of the projected consumptive uses indicates that the impacts would exceed those determined under the diversion scenarios evaluated. The triggering mechanism employed in this study would become less effective in time, due to reduced water supplies. In addition, consumptive uses impacts would exceed those of the current diversion rates. In view of the magnitude of projected future consumptive uses, the plan used for the regulation of Lake Ontario (1958-D), or the IJC criteria governing it, will need major revision by the turn of the century.

SECTICN 9

FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

9.1 General

This section summarizes the findings, conclusions and recommendations reached by the International Great Lakes Diversions and Consumptive Uses Study Board. The Board was charged to examine the effects of existing and proposed new diversions within, into and out of the Great Lakes basin and the effects of existing and the reasonably foreseeable pattern of consumptive uses on Great Lakes levels and outflows. In particular, the Commission requested the Board to assess the effects of varying the rates of existing diversions during periods of extreme levels on the Great Lakes.

Various diversion management scenarios were developed within the present physical capacities of the existing works and evaluated hydrologically, economically and environmentally. Also, consumptive uses for 1975 were determined and projected to the year 2035. The impact of the projections was evaluated hydrologically and a qualitative economic assessment of the projections was made. The Board's findings, conclusions, and recommendations are described below.

9.2 Findings

a. THE EXISTING DIVERSIONS HAVE PRODUCED CHANGES IN GREAT LAKES LEVELS AND OUTFLOWS.

The theoretical effects of the major diversions of water within the Great Lakes basin are shown on Table 9-1. This table shows that, based upon the approximate existing rates of these diversions, each diversion has had an effect over the total range of levels on each of the Great Lakes.

The diversions have had an impact on the long-term mean outflow from each of the lakes, increasing Lake Superior outflows by 5,600 cfs and that of Lakes Michigan-Huron, Erie and Ontario by about 2,400 cfs. Lakes Michigan-Huron and Erie outflows are directly related to their levels. The impacts of the existing diversions on the actual levels of Lakes Superior and Ontario are not readily discernible, due to the limitations incorporated by regulation.

b. DIVERSION RATES COULD BE MODIFIED WITHOUT STRUCTURAL CHANGE AT EXISTING DIVERSION LOCATIONS.

Examination of the in-place structures and capacities indicates that it is physically possible to reduce the Long Lac/Ogoki Diversions into the Great Lakes system from the present rate of approximately 5,600 cfs to zero; to vary the Lake Michigan Diversion at Chicago out of the system from the current rate of about 3,200 cfs to approximately 12,000 cfs for short

Table 9-1
THEORETICAL EFFECT OF EXISTING DIVERSION RATES ON
GREAT LAKES WATER LEVELS
(IN FEET)

DIVERSION	RATE (CFS)	SUPERIOR MEAN	SUPERIOR MAX	SUPERIOR MIN	SUPERIOR RANGE	MICHIGAN-HURON MEAN	MICHIGAN-HURON MAX	MICHIGAN-HURON MIN	MICHIGAN-HURON RANGE	ERIE MEAN	ERIE MAX	ERIE MIN	ERIE RANGE	ONTARIO* MEAN	ONTARIO* MAX	ONTARIO* MIN	ONTARIO* RANGE
Long Lac/ Ogoki	5,600	+.21	+.12	+.85	-.73	+.37	+.36	+.43	-.07	+.25	+.26	+.28	-.02	+.22	+1.26	+1.47	-.21
Lake Mich. at Chicago	3,200	-.07	0	-.06	+.06	-.21	-.20	-.24	+.04	-.14	-.15	-.15	0	-.10	-1.82	-.48	-1.34
Welland Canal	9,400	-.06	0	-.06	+.06	-.18	-.18	-.18	0	-.44	-.42	-.48	+.06	0	-.07	+.01	-.08
Combined	5,600 3,200 9,400	+.07	+.11	+.73	-.62	-.02	-.06	+.04	-.10	-.33	-.32	-.36	+.04	+.08	+.64	+.59	+.05

The above table reflects the theoretical impacts of the existing diversion rates by reducing the current rates to zero, singularly and in combination. It should be noted that the regulation plans in operation on Lakes Superior and Ontario have been designed to accommodate these diversions and satisfy the International Joint Commission's criteria for the regulation of those lakes. If these diversions had not been present, the regulation plans would be different producing the approximate same regime of levels.

*Lake Ontario levels computed under Plan 1958-D without application of International St. Lawrence River Board of Control discretionary deviations.

Notes:

1. Under Max, Min and Mean, minus signifies that the diversion impact has been to lower the lake in question, plus signifies the reverse.

2. Under Range, minus signifies that the range has been reduced, plus signifies the reverse.

3. The Study Board has evaluated a rate of 9,400 cfs for the Welland Canal, a rate which could occur in the near future due to increasing vessel traffic, although the current diversion rate (1980) is 9,200 cfs. The evaluation of a 9,200 cfs rate would give results similar in magnitude to those figures presented above.

periods of time or down to zero; and to vary the outflow from Lake Erie through the Welland Canal from the present rate of 9,200 cfs up to 11,000 cfs for short periods of time or down to zero. However, in the case of the Lake Michigan Diversion at Chicago, downstream constraints, during certain periods of the year, would not permit the 12,000 cfs maximum, limiting the possible average annual flow rate to approximately 8,700 cfs. Likewise, on the Welland Canal, the 11,000 cfs maximum flow rate poses problems to navigation and causes canal bank damage. A more practical limit, on a maximum average annual basis, would be in the order of 9,400 cfs. These alterations in flow could be accomplished without physical changes to the existing structures or without additional construction and would, if implemented, alter the net water supplies to the Great Lakes.

c. BY MANAGEMENT OF THE DIVERSIONS IT IS POSSIBLE TO IMPACT ON THE GREAT LAKES OUTFLOWS AND EXTREME HIGH LAKE LEVELS, BUT SUCH MANAGEMENT WOULD RESULT IN A NET ECONOMIC LOSS AND SOME UNQUANTIFIABLE ENVIRONMENTAL IMPACTS.

Reduction in Great Lakes water supplies during periods of high lake levels, which could be achieved by altering diversion rates, would produce a general lowering of the maximum levels but, at the same time, there would be a small lowering of the minimum levels and a net reduction in the range of levels. In the case of the maximum-effect diversion scenario, the resultant regime of levels would generate, on an average annual basis, some economic benefits to coastal zone interests, ($6.0 million) and recreational beach users ($1.8 million). However, it would cause economic losses to navigation ($13.8 million), power ($61.3 million) and recreational boating interests ($1.6 million). Thus, the net economic loss would be in the order of $69 million on an average annual basis, the predominant impact being felt in power generation.

A review of the published literature pertaining to the Great Lakes natural resources (fisheries and wetlands, in particular) indicates that the ecological effects of the maximum-effect diversion scenario are not definable in a quantitative sense using existing data. Although any ecological changes which may result are likely to be adverse, there is no conclusive evidence that these changes would be significant in magnitude. However, the effects may be subtle and indirect and may be additive or synergistic to other stress factors which the system's resources are already experiencing.

d. ANY ALTERATIONS IN DIVERSION RATES TO RAISE THE EXTREME LOW LAKE LEVELS AND OUTFLOWS WOULD BE INFEASIBLE.

It is not possible to increase the inflow from the Albany River basin through the Long Lac/Ogoki Diversions, with existing structures, during periods of low water on the Great Lakes. The meteorological conditions in the diversion area are similar to those in the Lake Superior basin; hence, during periods of drought there is little opportunity to bring additional water from that source into the Great Lakes system.

Reduction of the Lake Michigan Diversion at Chicago is considered impractical. Of the total present diversion authorized by the U.S. Supreme Court, approximately 60 percent is for water supply to the Metropolitan Chicago area. The remainder consists of storm water runoff from the diverted basin, or water used for navigation and water quality improvement purposes in the Chicago Sanitary and Ship Canal and Calumet-Sag Channel.

In order to use the Welland Canal to raise low levels on Lake Erie, the diversion would have to be decreased. To do this, a reduction in, or elimination of, a component of the flow used by Ontario Hydro for power generation at the DeCew Falls plants would be necessary. However, the resulting economic loss to power would outweigh the benefits accruing to navigation and recreational interests. Total closure of the canal to achieve a zero diversion rate would sever the Great Lakes navigation system between Lakes Erie and Ontario, and therefore is not a practical concept.

Closure of the New York State Barge Canal to achieve a zero diversion rate would have no effect on Great Lakes water levels, for reasons stated in Finding "e".

e. THE EXISTING DIVERSION OF WATER THROUGH THE NEW YORK STATE BARGE CANAL HAS NO MATERIAL IMPACT ON GREAT LAKES LEVELS, NOR WOULD ANY MODIFICATIONS THEREOF.

The New York State Barge Canal has a very limited capacity and draws its water from the Niagara River at Tonawanda, New York. Tonawanda is located downstream of the natural hydraulic control section of the Niagara River. Hence, any water withdrawn below the hydraulic control section has no effect on Lake Erie or the lakes upstream. Neither is there any impact downstream, since the water is returned to Lake Ontario through various tributaries to that lake. There is however, an impact on power; i.e., a reduction of water available for power generation on the Niagara River. The International Joint Commission has not exercised control over flows in the canal. The Board has not attempted to interpret the Commission's authority to exercise such control. However, the amounts of water diverted are reported to the two governments by the International Niagara Committee.

f. DIVERSION OF WATER INTO LAKE SUPERIOR FROM LONG LAC/OGOKI HAS AVERAGED 5,600 CFS SINCE ITS INCEPTION.

By an exchange of notes in 1940 between the Governments of Canada and the United States, which is also referred to in the Niagara Treaty of 1950, Ontario Hydro was authorized to withdraw from the Niagara River or Welland Canal 5,000 cfs of the water diverted from the Albany River basin through the Long Lac/Ogoki Diversions. The figure of 5,000 cfs was an estimate of the average flow that would be diverted at both locations. However, the actual diversions since inception have averaged 5,600 cfs.

The overall effect of the 5,600 cfs Long Lac/Ogoki Diversions is to raise the mean level of Lake Superior by 0.21 foot, Lakes Michigan-Huron by 0.37 foot, Lake Erie by 0.25 foot, and Lake Ontario by 0.22 foot. The effect of the difference between the 5,000 cfs referred to in the notes and treaty and the 5,600 cfs, is to raise the mean level of Lakes Superior, Erie and Ontario by 0.02 foot and Lakes Michigan-Huron by 0.04 foot. These figures are included in the above noted overall effects. The increased water supply of 600 cfs has resulted in an average annual net economic benefit to the system of approximately $11.3 million. This is based upon average annual losses to coastal zone interests of approximately $700,000 and average annual benefits to navigation and power generation interests of approximately $1.8 million and $10.2 million, respectively. There is no international control exercised under the Boundary Waters Treaty over these diversions. However, the amounts of water diverted are reported to the International Joint Commission by the International Lake Superior Board of Control.

g. THE WELLAND CANAL DIVERSION HAS VARIED OVER TIME AND AVERAGED APPROXIMATELY 9,200 CFS IN 1980.

Water has been diverted from Lake Erie to operate the Welland Canal between Lakes Erie and Ontario since 1829. Steadily increasing vessel traffic over the years has resulted in a gradual increase in the water required for lockage purposes. The canal was adapted for power purposes in 1887. Since that date, modifications and improvements have been made which increased its capability to convey water from the canal for power. As a result of increased water demand for both power and navigation, the Welland Canal diversion has grown from an annual average of about 300 cfs in the 1800s to more than 8,000 cfs in the mid-1950s. The average annual flow in the canal for the period 1950 to 1976 was 7,600 cfs. Since the inception of the study in 1977, the demand for water has further increased and is currently (1980) averaging on an annual basis about 9,200 cfs (power 6,900 cfs; navigation 1,300 cfs; and water supply and dilution water 1,000 cfs). The diversion scenario whereby the Welland Canal rate would be increased from an annual average of 7,000 cfs to 9,000 cfs thus has become a reality during the course of this study. There are indications that, with increasing vessel traffic, the demand for water in the canal could rise slightly to an annual average of 9,400 cfs in the near future. The International Joint Commission has not exercised control over flows in the canal. The Board has not attempted to interpret the Commission's authority to exercise such control. However, the amounts of water diverted are reported to the two governments by the International Niagara Committee.

h. THE LAKE MICHIGAN DIVERSION AT CHICAGO HAS VARIED OVER TIME AND SINCE 1970 HAS AVERAGED 3,200 CFS.

Water has been diverted from Lake Michigan at Chicago since 1848. Usage of water has varied over the years and was at its maximum annual rate in 1928, when the average discharge was 10,000 cfs. However, since 1925 the flow out of Lake Michigan through the Sanitary and Ship Canal has been controlled by U.S. Supreme Court decisions. The latest decree issued in 1967 and amended in 1980 limited the diversion, including domestic pumpage, to 3,200 cfs, averaged over a 40-year period. In addition, the amendment stated this diversion is not to exceed 115 percent of the 3,200 cfs value in any one accounting year. There is no international control exercised under the Boundary Waters Treaty over this diversion.

i. THERE ARE NO KNOWN SIGNIFICANT NEW OR CHANGED DIVERSIONS PROPOSED FOR THE GREAT LAKES.

The Board's investigation did not reveal any federal, state or provincial sponsored or approved proposed new or changed diversions within, into or out of the basin which have, or may have, material effects on water levels and flows of the basin.

j. CONSUMPTIVE USES OF WATER ARE PROJECTED TO INCREASE FROM THE 1975 RATE OF 4,900 CFS TO AN AMOUNT WHICH COULD RANGE FROM APPROXIMATELY 16,000 CFS TO 37,000 CFS BY THE YEAR 2035.

Seven water use sectors were adddresed in the consumptive uses projections: municipal, rural domestic, manufacturing, mining, stock watering, irrigation and thermal power generation. Over the 60-year projection period, 78 to 91 percent of all the projected consumptive uses of water are attributed to three of the seven water use sectors - municipal, manufacturing and thermal power generation - although the relative significance of each of these major sectors will change with time. While varying considerably among water use sectors and areas within the Great Lakes, basin wide consumptive water uses are expected to remain a relatively constant 6.5 percent of water withdrawals over the time period.

The validity of consumptive uses projections relates directly to the assumptions upon which they are based. Varying these assumptions produces high and low estimates of future use. The most likely projection (MLP) of consumptive water use increases to 25,400 cfs by the year 2035, from the current rate (1975) of 4,900 cfs. The high estimate is 36,500 cfs and the low estimate is 16,300 cfs by the year 2035. This range of approximately $\pm$ 40 percent about the most likely projection for 2035 reflects the inherent uncertainties in the long-range forecasting of the parameters upon which consumptive use estimates are based. Currently, approximately 88 percent of the consumptive uses occur in the United States and 12 percent in Canada. This proportion is expected to change only slightly, being 82 percent in the United States and 18 percent in Canada by the year 2035.

k. THE CONSUMPTIVE USES OF WATER REDUCE THE NET WATER SUPPLY TO THE LAKES, THEREBY LOWERING LAKE LEVELS, RESULTING IN ECONOMIC BENEFITS TO COASTAL ZONE INTERESTS AND LOSSES TO NAVIGATION AND POWER INTERESTS.

As a result of the most likely projection of increases in consumptive use within the Great Lakes system, the average levels of Lake Superior could be lowered in 60 years by as much as 0.3 foot; Lakes Michigan-Huron by 0.7 foot; Lake Erie by 0.8 foot; and Lake Ontario by 2.4 feet. The lowering of levels would provide economic benefits to coastal zone and recreational beach interests, while causing large losses to navigation, power, and recreational boating interests. The reduction in water supplies, due to consumptive uses is reflected in reduced average outflows from each of the lakes, cumulatively greater downstream through the system, with the maximum impact therefore occurring in the Lake Ontario outflows through the St. Lawrence River. The MLP projection of total consumptive use in 2035 represents an increase of 20,500 cfs from 1975. This increase is equivalent in magnitude to 8.6 percent of the mean outflow of the St. Lawrence River.

Consumptive uses represent a loss of water to the Great Lakes system and hence a redistribution of its inherent benefits from Great Lakes user interests to consumer interests. The determination of the economic value of the water to those consumer interests was considered to be beyond the scope of the Board's directive and available resources, because it would entail a very complex study of the value of water in its various forms of consumptive use. The significance of the Board's consumptive use study results should be evaluated, as appropriate, in the development of future Great Lakes water use policies.

1. CONSUMPTIVE USES IN THE FUTURE WILL LIMIT THE ABILITY OF THE CURRENT OPERATIONAL REGULATION PLAN FOR LAKE ONTARIO TO SATISFY THE CRITERIA CONTAINED IN THE COMMISSION'S ORDERS OF APPROVAL.

The Orders of Approval for the regulation of Lakes Superior and Ontario contain lake level criteria which must be satisfied by the operating regulation plans. Evaluation of the impact of the consumptive uses MLP (to the year 2035) on the governing level criteria for Lake Superior, indicates that the present operating rule for the regulation of that Lake would not have to be modified in order to satisfy these conditions over the 60-year evaluation period. This is due to the fact that the projected consumptive uses increase over this period amounts to less than 600 cfs. However, this is not the case for Lake Ontario, which will receive the cumulative impact of all upstream increases in consumptive uses. The MLP indicates an increase in consumptive use within the Great Lakes basin over the next 60 years of approximately 20,500 cfs. If this projected increase does occur, the present operating plan, with its fixed limits, would be unable to satisfy both the Lake Ontario level and the St. Lawrence River flow criteria of the Orders of Approval in the not too distant future. At that time, a revision to the operating plan, or a change in the Orders of Approval, would be necessary.

9.3 Conclusions

The Board's conclusions are as follows:

a. The diversion rates into, within and out of the basin cannot be altered to reduce extreme high levels on the Great Lakes without causing an overall long-term net economic loss;

b. The diversion rates into, within and out of the basin cannot feasibly be altered to increase extreme low levels on the Great Lakes during periods of low supply;

c. Periodically, all diversions (regardless of size) should be monitored and their accumulated effects estimated, evaluated and reported upon so that appropriate public policies can be developed; and,

d. Consumptive uses should be periodically monitored and their impacts, along with various control strategies, studied so that appropriate public policies can be developed to minimize long-term adverse effects.

9.4 Recommendations

Based upon the above findings and conclusions the Board recommends that;

a. No further consideration be given to the concept of managing Great Lakes levels and outflows through the manipulation of the existing diversions; and,

b. The International Joint Commission, in light of conclusions (c) and (d) above, recommend to Governments that a mechanism be established for institutional consultation so that monitoring can be undertaken and appropriate public policies can be formulated to address the potential future impacts of new or increased diversions and consumptive uses.

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ANNEX A

DEPARTMENT OF STATE

Washington, D. C. 20520

C O P Y

February 21, 1977

Mr. William Bullard
Secretary, U. S. Section
International Joint Commission
1717 H Street, N. W.
Washington, D. C. 20440

Dear Mr. Bullard:

I have the honor to inform you that Governments of Canada and the United States have agreed, pursuant to Article IX of the Boundary Waters Treaty of 1909, and in light of the second recommendation contained in the International Joint Commission's Report entitled "Further Regulation of the Great Lakes", in response to the October 7, 1964 Reference from Governments, to request the Commission to examine into and report upon the effects of existing and proposed diversions within, into or out of the Great Lakes Basin, and the effects of existing and reasonably foreseeable patterns of consumptive uses on Great Lakes water levels and flows.

The Governments are concerned about the increasing demand for water to meet the needs of domestic and municipal supply and sanitation, navigation, industry, power generation, irrigation and other such uses, which will have increasingly significant socio-economic and environmental impact on all interests in the Great Lakes Basin.

During periods of extreme lake levels, attention in both countries has focused on the nature and effects of the various diversions within, into and out of the Basin. The Governments consider further study of these important hydrological features important in the context of the Commission's ongoing efforts to promote a greater understanding of the Great Lakes system and to investigate possibilities of enhanced levels regulation consistent with the conclusions of the Commission's Report.

In light of the foregoing, and with reference to the following criteria:

(a) Domestic water supply and sanitation;

(b) Navigation;

(c) Water supply for power generation and industrial purposes;

(d) Agriculture;

(e) Shore property, both public and private;

(f) Flood control;

(g) Fish and wildlife, and other environmental aspects;

(h) Public recreation; and

(i) Such other effects and implications which the Commission may deem appropriate and relevant,

the Commission is requested to examine into and report upon the following matters which have, or may have, material effects on water levels and flows of the Basin, including the international and Canadian reaches of the St. Lawrence River:

1. Existing and reasonably foreseeable patterns of consumptive uses of Great Lakes waters;

2. Existing diversions, including the Welland Canal and the New York State Barge Canal, and federal, state or provincially sponsored or approved proposed new or changed diversions, within, into or out of the Basin, and, in particular,

3. Existing diversions at Chicago and at Long Lac/Ogoki, and the proposed study and demonstration program authorized by United States P. L. 94-587 affecting the rate of diversion at Chicago.

The Commission, upon the availability of adequate funding, should proceed with the above studies as expeditiously as practicable, and report to Governments by March 1, 1979, and on an interim basis if deemed appropriate.

In the conduct of its investigation and the preparation of its report, the Commission shall make use of information and technical data heretofore available or which may become available in either country during the course of its investigations. In addition, the Commission shall seek the assistance, as required, of specially qualified personnel in Canada and the United States. The Governments shall make available or, as necessary, seek the appropriation of the funds required to provide the Commission promptly with the resources needed to discharge the obligations under this Reference fully within the specified time period. The Commission shall develop as early as practicable cost projections for the studies under Reference for the information of Governments.

An identical letter is being forwarded to the Canadian Section of the Commission by the Department of External Affairs.

Sincerely,

Richard D. Vine
Deputy Assistant Secretary
for Canadian Affairs

COPY

ANNEX B

Docket 104

INTERNATIONAL JOINT COMMISSION

DIRECTIVE TO THE

INTERNATIONAL GREAT LAKES DIVERSIONS AND CONSUMPTIVE USES STUDY BOARD

1. The Governments of the United States and Canada have forwarded the attached Reference, dated February 21, 1977, to the Commission for examination and report pursuant to Article IX of the Boundary Waters Treaty of 1909.

2. The Commission established the International Great Lakes Diversions and Uses Study Board on May 3, 1977, to undertake, through appropriate governmental or other agencies in the United States and Canada, the necessary investigations and studies and to advise the Commission on all matters which it must consider in making its reports to Governments under the attached Reference.

3. The Board shall undertake an investigation of the following matters which have, or may have, material effects on water levels and flows in the Great Lakes Basin, including the international and Canadian reaches of the St. Lawrence River:

(a) existing and reasonably foreseeable patterns of consumptive uses of Great Lakes waters;
(b) existing diversions, including Welland Canal and the New York State Barge Canal, and federal, state or provincially sponsored or approved proposed new or changed diversions, within, into or out of the basin, and in particular;
(c) existing diversions at Chicago and at Long Lac/Ogoki, and the proposed study and demonstration program authorized by United States P.L. 94-587 affecting the rate of diversion at Chicago.

In conducting this investigation, the Board shall examine the effects of the above on:

(a) domestic water supply and sanitation;

(b) navigation;

(c) water supply for power generation and industrial purposes;

(d) agriculture;

(e) shore property, both public and private;

(f) flood control;

(g) fish and wildlife, and other environmental aspects;

(h) public recreation; and

(i) such other matters as the Commission may indicate to the Board during the course of the study.

4. In its studies the Board should note the concerns of the Governments expressed in the Reference about the increasing demand for water to meet the needs of domestic and municipal supply and sanitation, navigation, industry, power generation, irrigation and other such uses, which will have increasingly significant socio-economic and environmental impact on all interest in the Great Lakes Basin.

5. The Board should in particular assess the effects of varying the rate of existing diversions during periods of extreme levels on the Great Lakes.

6. The Board shall prepare and submit for Commission approval by July 22, 1977, a plan of study for the investigations that it proposes to undertake, and a schedule of the estimated time and costs involved in the completion of each of the necessary phases of the study and submission of a final report to the Commission. In preparing its plan of study, the Board should be guided by the following considerations:

(a) Provision should be made for the investigation of all environmental impacts of the matters under investigation as described in paragraphs 3, 4 and 5 of this directive,

(b) The Board shall act as a unitary body, carrying out its investigations jointly in both countries as a coordinated and integrated effort, and

(c) Provision should be made, where appropriate, for public information and participation throughout the course of the study.

7. The Board shall carry out the programs in accordance with the plan of study approved by the Commission. If it appears to the Board at any time in the course of its investigations and studies that the programs should be modified, it shall so advise the Commission and request instructions.

8. The Board shall submit its final report, and appendices, if any, in the necessary quantity for public distribution, to the Commission no later than September 1, 1978.

9. In the conduct of its investigation and in the preparation of its report or reports, the Board should make use of information and technical data heretofore available, or which may become available during the course of the investigation. The Board's attention is specifically drawn to the Final Report of the International Great Lakes Levels Board, and the Report of the International Joint Commission on Further Regulation of the Great Lakes.

10. The Board will consist of a United States Section and a Canadian Section, each having five (5) members. The Commission will appoint one member of each Section to be Chairman of that Section. At the request of any member, the Commission may approve in each case an alternate member to act in the place and stead of such member whenever the said member, for any exceptional reason, is not available to act as a member of the Board.

11. Members of the Board, and of its committees and working groups, whether or not employed by departments or agencies of government, are not representatives of their employers. They serve in a personal and professional capacity under the direction of the Commission, and their employers or superior officers are not committed in any way by the actions of the individual members of the Board.

12. The Chairmen of the two Sections shall be joint Chairmen of the Board and shall be responsible for maintaining proper liaison between the Board and the Commission and between their respective sections of the Board and the corresponding sections of the Commission.

13. Each Chairman shall ensure that the other members of his Section of the Board are informed of all instructions, inquiries and authorizations received from the Commission; also of activities undertaken by or on behalf of the Board, progress made and any developments affecting such progress.

14. A Chairman, after consulting the other members of his Section of the Board, may appoint a Secretary of that Section and a Public Information Officer of that Section. Under the general supervision of the Chairman, these individuals shall carry out such duties as are assigned to them by the Section.

15. The Board may establish such committees and working groups as may be required to discharge its responsibilities effectively and may enlist the cooperation of federal, provincial or state departments or agencies in the United States and Canada. The duties and

composition of any such committees shall be subject to prior approval by the Commission. The Board should consider and advise the Commission whether it would be desirable to appoint a coordinator to assist the Board in its investigation in view of the severe time constraints imposed on the study. Board and Committee members will make their own arrangements for reimbursement of necessary expenditures for travel.

16. The Board shall maintain liaison with the International Lake Erie Regulation Study Board, the International Lake Superior Board of Control, the International Niagara Board of Control and the International St. Lawrence River Board of Control, so that each may be aware of any activities of the other Boards which may be useful to it or may have a bearing on its activities.

17. The Chairmen shall keep the Commission currently informed of the Board's plans and progress and of any developments, actual or anticipated, which are likely to impede, delay or otherwise affect the carrying out of the Board's responsibilities.

18. The Chairmen shall submit, at least semi-annually and more often if necessary, reports to the Commission describing the progress that has been made and any problems that have arisen in the investigation. All such reports shall be sent to the Secretaries of the Commission. Regular semi-annual reports should be submitted at least two weeks prior to the Commission's April and October meetings.

19. If, in the opinion of the Board, there is a lack of clarity or precision in any instruction, directive or authorization received from the Commission, the matter shall be referred promptly to the Commission for appropriate action.

20. Documents, letters, memoranda and communications of every kind in the official records of the Commission are privileged and become available for public information only after release by the Commission. The Commission considers all documents in the official records of the Board or of any of its committees to be similarly privileged. Accordingly, all such documents shall be so identified and maintained in separate files. They shall become available for public information only after Commission approval.

21. In its dealing with the public and the news media, the Board shall observe the principles of the attached documents on Public Relations Policy dated 27 July 1973 and 20 September 1974 of the Commission as supplemented by the provisions of the study plan of the Board when approved by the Commission.

Issued this 10 May 1977

William A. Bullard David G. Chance

Joint Secretaries
International Joint Commission

ANNEX C

Public Involvement

The Study's Public Involvement Program Ad-Hoc Group was charged, basically, with the publication of a newsletter, organization and coordination of public workshops, and the establishment of liaison with the news media and the public sector.

There have been five issues of the newsletter published, both in English and in French. A copy of the English version of all the newsletters plus the French version of issue number two is included in this Annex. Also, included is a report on the public workshops.

Diversions

INTERNATIONAL GREAT LAKES

DIVERSIONS AND CONSUMPTIVE USES STUDY

NO. 1 • NOVEMBER, 1978

U.S./CANADA STUDYING MAN'S IMPACT ON GREAT LAKES WATER RESOURCES

In February 1977 the International Joint Commission (IJC) was directed by the United States and Canadian governments to undertake a study of the diversions and consumptive uses in the Great Lakes basin.

The need for such a study was determined by a previous investigation of Great Lakes water levels by the International Great Lakes Levels Board (IGLLB).

The IGLLB study showed that many users of the Great Lakes system are affected by the variation in lake levels and outflows, particularly during periods of extremely high or low water supplies.

The management plans presented in the IGLLB's report showed that regulation of Lakes Michigan-Huron was not economically justified, but regulation of Lake Erie did hold some promise.

The Great Lakes Levels Board's responsibilities did not include a consideration of the impact or benefits which could be derived from the management of basin diversions.* Therefore, the IJC recommended a separate study on diversions in its report to the Governments of Canada and the United States, dated April 1976. This was partly due to the degree of interest expressed by the public.

Consumptive uses of water within the system also affects flows and consequently levels, but these effects also were not examined in detail by the Great Lakes Levels Board. This was noted in its report with a recommendation that they be studied further.

The two governments, in response to the IJC's report, recognized the need for more information on the effects of diversions and consumptive uses. They directed the IJC to conduct a more thorough investigation of these matters.

Therefore, in May 1977 the Commission established the International Great Lakes Diversions and Consumptive Uses Study Board to undertake the necessary studies and investigations. At the same time, the Commission was also directed to conduct a further study of the regulation of Lake Erie and created the International Lake Erie Regulation Study Board to determine the feasibility of limited regulation of that lake. Active liaison is being maintained between the two Study Boards.

Similarly, liaison is being maintained with other IJC Boards serving the Great Lakes area and with the U.S. Increased Lake Michigan Diversion at Chicago Demonstration and Study Program. This program is investigating the feasibility of increasing the amount of water diverted from Lake Michigan at Chicago into the Illinois Waterway during periods of above normal lake levels.

TERMINOLOGY

*Within the context of this study, the following terms will be used as defined below:

Diversions - man-made modifications such as canals, dams, etc., which alter the inflows, outflows or flows between lakes in the Great Lakes system. The principal diversions considered in this study are: (1) Long Lake/Ogoki, which increases the natural supply of water to all lakes; (2) Lake Michigan Diversion at Chicago, which reduces the supply to lakes other than Lake Superior; and (3) Welland Canal, which lowers the levels of Lakes Erie and Michigan-Huron.

Consumptive Use - refers to the portion of water withdrawn or withheld from the Great Lakes system for various uses that is not returned. Consumptive uses which will be considered include: agricultural (e.g., irrigation, livestock watering), manufacturing, and domestic. Water so consumed in any of the separate lake basins constitutes a reduction in the net water supply to that lake and also reduces the water supply to downstream lakes.

Metric Equivalent - one cubic foot per second (cfs) equals 0.0283 cubic metre per second.

STUDY ORGANIZATION

The following is the membership of the International Great Lakes Diversions and Consumptive Uses Study Board:

United States

Maj. Gen. Richard L. Harris, Chairman
Corps of Engineers

Mr. William Marks
State of Michigan

Mr. Frank Kudrna
State of Illinois

Mr. Clifford H. McConnell
State of Pennsylvania

Mr. James D. Hebson
Federal Energy Regulatory Commission

Canada

Mr. Ralph L. Pentland, Chairman
Department of Environment

Mr. Ralph H. Smith
Department of Transport

Mr. Grant Mills
Ontario Ministry of the Environment

Mr. Betrand Bouchard
Quebec Ministry of Natural Resources

Mr. Roy A. Walker
Ontario Hydro

The Board subsequently established a Working Committee of a similar composition to carry out the necessary studies. In order to utilize available expertise, the Working Committee established subcommittees; namely, Diversions, Consumptive Uses, and Environmental Evaluation, to cover these prime areas. Each subcommittee is comprised of one Canadian and one U.S. member.

The major objectives of the Study Board are: (1) to determine the effects of current diversions on levels and flows in the Great Lakes system, including the reach of the St. Lawrence River from Lake Ontario to Trois Rivieres, Quebec, and to investigate the possible effects of variations in these diversions; (2) to determine the current and projected future consumptive uses and their effects on lake levels. Hydrologic and economic impacts will be assessed with respect to shoreline interests, navigation, and power production; and the environmental consequences will be examined for the Great Lakes system, and along the diversion routes.

HIGHLIGHTS OF THE STUDY SCHEDULE

November 1977 - Presentation to the IJC of the Study Board's Plan of Study

November/December 1977 - IJC Public Hearings on the Plan of Study

Fall 1978 - Preliminary Possible Diversion Management Alternatives Developed

Winter 1979 - Public Comment on Preliminary Management Alternatives

Spring 1979 - Completion of Detailed Hydrologic, Environmental, and Economic Evaluations

Fall 1979 - Public Workshops on Study Results

1980 - Report Finalized and Submitted to IJC

LET US KNOW YOUR VIEWS!

Diversions is published by the International Great Lakes Diversions and Consumptive Uses Study Board.

Please help us establish a mailing list and let us know of your interest in this study by filling out the enclosed form and mailing it in the enclosed, self-addressed envelope. Other questions and comments should be sent to the Study Board c/o Public Affairs Office, U.S. Army Corps of Engineers, Box 1027, Detroit, Michigan 48231, or c/o Department of Environment, Inland Waters Directorate, Ottawa, Ontario, K1A0E7.

Thank you for your interest!

LET US KNOW YOUR VIEWS!

The views, desires, and needs of the public are essential inputs to the planning process of the International Great Lakes Diversions and Consumptive Uses Study. In order to incorporate these views into our program, we need your input.

If you are interested in receiving further issues of **Diversions** and/or interested in attending public workshops on the study, please indicate this on the following form, then return in the enclosed envelope. To be of value, your replies should be given before December 22, 1978.

Also, please tell us what your interests are with respect to this study, and the locations where you would be willing to attend workshops.

1. Name ______________________________

   Address ______________________________

   ____

2. What is your interest in this study? (Check one or more; detail, if necessary)

   _____ Consumptive Use
   _____ Shore Property
   _____ Navigation
   _____ Hydroelectric Power
   _____ Recreation
   _____ Political Concern
   _____ Fish and Wildlife
   _____ Special Interest Group or Agency (please name)
   ____
   _____ Other (please describe)
   ____
   ____

3. Do you wish to receive further issues of **Diversions** (this newsletter)?

   _____ Yes _____ No

4. What is your language preference?

   _____ English _____ French

5. A tentative series of public workshops would be designed to inform the public and special interest groups who are either interested or affected by the study and, at the same time, provide an opportunity for the public to voice their comments and recommendations. Would you attend such a workshop at a location convenient for you?

   _____ Yes _____ No Comments: ______________________________

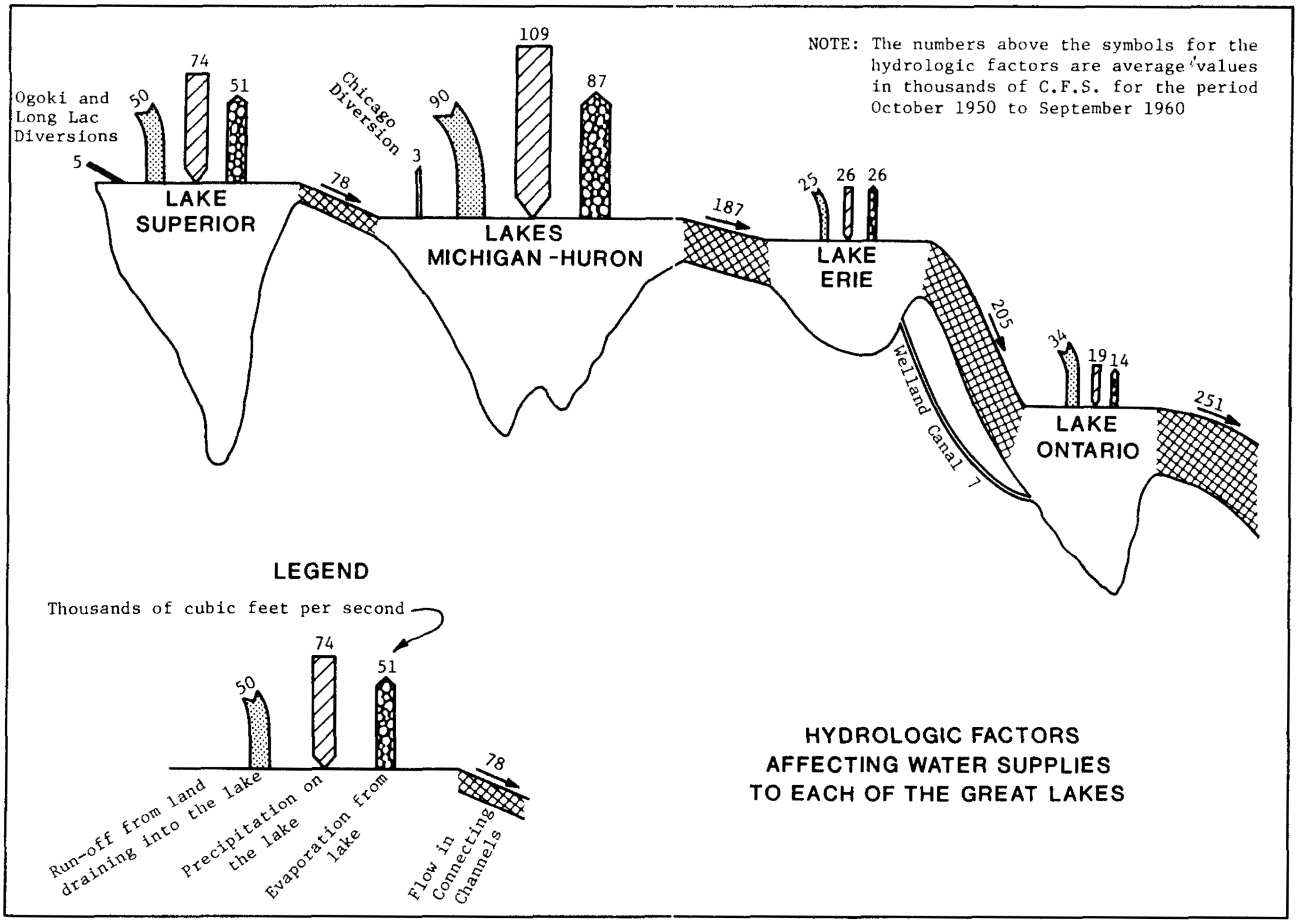
6. Of the following locations in the Great Lakes area, please check those locations where you would attend a workshop:

   _____ Sault Ste. Marie, Michigan or Ontario
   _____ Windsor, Ontario, or Detroit, Michigan
   _____ Sarnia, Ontario, or Port Huron, Michigan
   _____ Duluth, Minnesota
   _____ Thunder Bay, Ontario
   _____ Buffalo, New York State, or Niagara Falls, Ontario
   _____ Toronto, Ontario
   _____ Chicago, Illinois
   _____ Montreal, Quebec

Please return this form in the enclosed self-addressed envelope.

PROPOSED MANAGEMENT ALTERNATIVES

In order to respond to the IJC's directive, the Board will investigate the impacts of existing and any proposed diversions on the Great Lakes levels and flows. The current average diversion rates are 5,000 cubic feet per second (cfs) from Long Lake and Ogoki Reservoirs into Lake Superior, 3,200 cfs from Lake Michigan into the Illinois Waterway at Chicago, and 7,000 cfs in the Welland Canal between Lake Erie and Lake Ontario. These values are shown on the following diagram. Also shown on this diagram are other causative factors which affect lake levels and reflect the relative magnitude of each of the factors.



This figure has been taken from the IJC report "Further Regulation of the Great Lakes", 1976.

The changes in each individual diversion that are being considered for evaluation are as follows:

(1) Long Lake/Ogoki Diversions - These can be maintained at their current average rate, reduced to a value of 2,500 cfs, or shut off. Therefore the values of 5,000, 2,500, and 0 cfs are to be evaluated.

(2) Lake Michigan Diversion at Chicago - Part of this diversion could also be shut off but a figure of 0 cfs is not totally practical since the domestic consumption and navigation in the area would have to be satisfied; however, for a point of reference, 0 cfs will be evaluated. This diversion may also be increased up to an average of approximately 8,100 cfs which is the maximum condition of the U.S. Increased Lake Michigan Diversion at Chicago Demonstration and Study Program. Therefore, the average flow rates of 0, 3,200, 6,600, and 8,100 cfs will be evaluated.

(Continued on page 4)

MANAGEMENT ALTERNATIVES

(Continued from page 3)

(3) Welland Canal - Part of this diversion could also be shut off, but a figure of zero is not practical since it is necessary for navigation between Lakes Erie and Ontario and for the generation of power. The current average release through the canal is 7,000 cfs, but it has the capacity to pass 9,000 cfs on a yearly average basis. Therefore, both 7,000 and 9,000 cfs will be evaluated. Also, for a point of reference, 0 cfs will be evaluated.

These diversions will be evaluated singularly and in combinations. The evaluations will be made utilizing a mathematical model of the Great Lakes system.

Each individual or combination alternative will be evaluated using representative indicators to determine when adjustments in flow rates should take place. The indicators being considered are lake levels, water supply to the system, and/or a forecast of extreme water supply conditions.

Preliminary indications are that changes in water levels resulting from possible management diversions would be a half foot or less.

It is emphasized that the above management alternatives are theoretical only and will not necessarily be implemented.

● ● ●

☆U.S. GOVERNMENT PRINTING OFFICE: 1978—650-230

Diversions

INTERNATIONAL GREAT LAKES DIVERSIONS AND CONSUMPTIVE USES STUDY

NO. 2 • JUNE, 1979

DIVERSIONS NEWSLETTER BRINGS 21% RESPONSE

The first issue of **Diversions**, published by the International Great Lakes Diversions and Consumptive Uses Study Board, was well received, and we express our appreciation to all who responded to our request for public views and concerns.

Of 14,500 newsletters mailed to various publics throughout the Great Lakes Basin, over 3,100 persons, or 21 percent of the total, returned the accompanying mail-back survey indicating their interest in this study and in having workshops.

We apologize that, due to circumstances beyond our control some people received the newsletter after the dead line for response, and that self-addressed envelopes were inadvertently left out of a number of newsletters. We extend a special thank you to those recipients who nevertheless responded.

The respondents have been divided into the following categories: unaffiliated members of the public, including individual shore property owners, 63 percent of the respondents; representatives of government at all levels, 13 percent; representatives of industry, 8 percent; academia, 8 percent; special interest groups, including environmental groups and shore associations, 7 percent; and media, 1 percent.

The shore property issue generated the most response; 57 percent of the respondents expressed concern about waterfront property and accompanying problems of erosion and flooding. Recreation ranked second, then fish and wildlife, navigation, consumptive uses, political concerns, and hydroelectric power, respectively.

We regret that we cannot personally answer all the questions and comments received. However, those most frequently mentioned are addressed on pages 3 and 4 of this issue of **Diversions**. Several inquiries of a technical nature have received individual replies.

Of the total respondents, 75 percent expressed a desire to attend at least one workshop concerning this study. Although interest was widespread throughout the Great Lakes Basin, the largest number of responses were concentrated in the Chicago, Detroit-Windsor, and Buffalo-Toronto areas.

Public workshops are tentatively scheduled at these sites and at least one location in the Lake Superior Basin. It is anticipated that they will be held in Spring, 1980. At the workshops, the Study Board will discuss hydraulic and economic impacts on power, navigation and shoreline interests of the diversion alternatives. The workshop dates will be publicized in a third issue of **Diversions**, as well as in local media.

In addition, we will welcome written correspondence from members of the public unable to attend a workshop due to distance or other factors. Your knowledge, as members of the affected publics, is valuable to the progress and results of this study, and all views will be considered within its total context.

See page 4 for the addresses where correspondence should be sent.

Staff members of the Public Affairs Office, U.S. Army Corps of Engineers, in Detroit, Michigan, review stacks of **Diversions** surveys returned from members of the public. Over 3,100 responses were received and tallied.

HIGHLIGHTS OF STUDY PROGRESS

Diversion Alternatives

Studies are progressing on the evaluation of impacts under all combinations of diversion alternatives listed in the first issue. (These are repeated below.) During these studies, detailed evaluation of conditions in the Illinois Waterway (Chicago Diversion[1]) indicated that the opportunity to increase flows above the present rate of 3200 cfs had been underestimated. As a result of reevaluation this value has now been set at an approximate annual average of 8700 cfs instead of 8100 cfs previously reported.

(1) Long Lake/Ogoki Diversions – The values of 5,000, 2,500, and 0 cfs are to be evaluated.
(2) Lake Michigan Diversion at Chicago[1] – Part of this diversion could also be shut off but a figure of 0 cfs is not totally practical, since the domestic consumption and navigation in the area would have to be satisfied; however, for a point of reference, 0 cfs will be evaluated. Therefore, the average annual flow rates of 0, 3,200 (current average), 6,600 and 8,700 cfs will be evaluated.
(3) Welland Canal – Part of this diversion could also be shut off, but a figure of zero is not practical, since it is necessary for navigation between Lakes Erie and Ontario and for the generation of power. The current average annual release through the canal is 7,000 cfs, but it has the capacity to pass 9,000 cfs on a yearly average basis. Therefore, both 7,000 and 9,000 cfs will be evaluated. Also, for a point of reference, 0 cfs will be evaluated.

These diversions will be evaluated singly and in combinations.

Each individual or combination alternative will be evaluated using representative indicators to determine when adjustments in flow rates should take place. The indicators being considered are lake levels, water supply to the system, and/or a forecast of extreme water supply conditions.

Consumptive Uses

Preliminary projections have been made of consumptive uses in the system through to the year 2035. These uses represent a progressive reduction in the water which will be flowing through the lakes in the future. By "routing"[2] the projected reduced supplies through the system, their effects on lake levels will be computed, and in turn their economic impacts evaluated.

Environmental Evaluation

Environmental evaluation studies are focusing on three areas: the Great Lakes-St. Lawrence system as a whole; the Illinois Waterway and the Long Lake-Ogoki Diversions. In view of the limitations of budgetary and manpower resources available to the Board, the extent of these environmental studies will be governed by the economic impacts of the various alternatives being considered. In other words, any alternative which has to be discarded as economically unacceptable would not justify the expenditure of these resources on the determination of its environmental impacts.

Public Involvement

The survey of public interest conducted through the November 1978 issue of **Diversions** provided a gratifying response. The most frequently expressed concerns are addressed in this newsletter. We expect to be holding public workshops on the emerging study results in Spring 1980.

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[1] Lake Michigan Diversion at Chicago, hereafter simply referred to as the Chicago Diversion.

[2] "Routing" is a hydraulic computation whereby changes in the flows into, between and out of the Great Lakes system, together with other factors such as precipitation and evaporation, are converted to changes in lake levels.

SOME ANSWERS TO YOUR QUESTIONS

1. **QUESTION**: Why is the study being limited to the analysis of existing major diversions? What would be the effects of altering the current flow rates of these diversions on the Great Lakes system?

ANSWER: Study limits are defined by the February 21, 1977, Reference from the two Governments to the International Joint Commission. This Reference requested that a study be conducted to examine the feasibility of altering the existing and/or proposed approved diversions within, into, or out of the Great Lakes Basin. While the study is not limited to the existing major diversions, previous studies of the Great Lakes system have indicated that only the major diversions of Long Lake/Ogoki, Welland Canal, and Chicago are of sufficient magnitude to have significant impacts on the water levels and flows of the system. Hence, the initial phase of the study has been concentrating on management plans for these diversions; any minor diversions such as the New York State Barge Canal will be addressed in a later phase.

The second portion of the above question is the reason for the study. Prior studies have dealt, in part, with the hydrologic effect of altering these diversions. This study will deal with the total question, presenting not only the hydrologic impact but also addressing the economic and synoptic environmental impacts. These are still in the process of being evaluated.

2. **QUESTION**: Under this study, are physical changes to the Great Lakes system being evaluated?

ANSWER: The Reference to the International Joint Commission does not provide for the investigation of physical changes to the Great Lakes system. The study is mainly dealing with the existing diversion channels and their physical capacities. Such matters as deepening channels and the proposed Black Rock Canal Diversion along the Niagara River are being considered by the Lake Erie Regulation Study under another Reference. Data produced in these two studies are being exchanged to insure coordination.

3. **QUESTION**: In light of the previously completed International Great Lakes Levels Board study, why is this study being conducted?

ANSWER: The International Great Lakes Levels Board (IGLLB) study investigated the various factors which affect the fluctuation of water levels and recommended actions to be taken to bring about a range of stage more beneficial to the users of the Great Lakes System. Throughout the progress of that study, fixed diversion rates were used. Those rates were authorized by law or through exchange of Notes between the United States and Canadian Governments. While the final report of the Great Lakes Levels Board discussed the impacts of existing diversions at their fixed rates, the impacts of managing the diversions were not considered as this was beyond the terms of reference for that study. Therefore, the IGLLB recommended that this be taken up as a separate study. Consequently, the Diversions and Consumptive Uses Study was requested by the two Governments.

4. **QUESTION**: How was the selection of membership on the Study Board determined?

ANSWER: The selection of members of IJC Boards is carried out by means of consultations between the IJC and state, provincial and federal governments. In this case, since both the Lake Erie and Diversion and Consumptive Uses References cover the same geographic area, members for each Board were chosen from the area where the greatest impact was felt to occur for the particular study. Both Boards were directed by the IJC to stay in close liaison and to freely exchange information.

5. **QUESTION**: What causes fluctuations in water levels and can such changes be controlled—perhaps to a more constant average level—to benefit the various Great Lakes interests involved?

ANSWER: These basic questions were examined in considerable detail by the IGLLB (1964-73), a study which is not being duplicated by this Board. In general, lake levels rise and fall seasonally in response to the annual hydrologic cycle and, in the long term, due to extended periods of wet or dry years. For example, increases in precipitation raise the levels; higher levels increase the outflows; greater outflows compensate by bringing down the levels. On the other hand, during periods of low precipitation, lake levels start to drop and outflows decrease to stabilize levels. Thus, without the intervention of man, lakes are naturally self-regulating. The natural regimes of outflows and levels of both Lake Superior and Lake Ontario, however, are modified by regulatory works constructed at their outlets (at Sault Ste. Marie and Cornwall/Massena, respectively). These works, with associated power generating and navigation facilities, serve to control the outflow, thereby impacting on the lake levels. The IGLLB study, aimed at determining whether **further** regulation of the lakes is feasible, showed that (i) some improvement in levels, with resulting net benefits, could be achieved by altering the operating plan for the Lake Superior works, (ii) regulation of Lakes Michigan/Huron by the construction of works in the outlet St. Clair/Detroit rivers is not economically feasible, and (iii) some possibility exists for regulating Lake Erie by constructing works at its outlet. As a result, the IJC has directed that a new operating plan for the regulation of Lake Superior be prepared by its Lake Superior Board of Control and an International Lake Erie Regulation Study Board was created to study regulation of that lake in greater detail. The IJC has also created the Diversions and Consumptive Uses Study Board which is addressing itself, in part, to determining whether improved lake level regimes can be achieved by modifying any of the diversions into and out of the Great Lakes Basin.

Some Answers to Your Questions (cont.)

6. **QUESTION:** Does the study take into account such factors as run-off to the lakes from the land and tributary rivers, rainfall, evaporation and evapo-transpiration, water used for power generation, and so on? Is it possible to computerize these factors?

ANSWER: Yes. All these (and many other) factors are built into the hydrologic, hydraulic and economic calculations involved. Of necessity, these calculations are computerized.

7. **QUESTION:** What are the Long Lake/Ogoki Diversions? Will they be increased? Is it realistic to consider reducing them to zero?

ANSWER: These diversions bring water into Lake Superior from rivers which originally flowed north-eastward into the Albany River system and onward into James Bay. These diversions have been in existence for about forty years for the purposes of log driving and hydroelectric power generation. Reducing these diversions to zero during periods when the Great Lakes are experiencing high supply is a physical possibility; however, in balancing the resultant economic benefits and losses to the Great Lakes System, the costs of replacing the lost power generation and of using an alternative log transportation system have to be considered. Conversely, the possibility of increasing these diversions during low supply periods on the Great Lakes has been considered. However, within the operating constraints on Lake Nipigon and Long Lake, these diversions are presently passing all the available water; hence, no increase in diversion is possible.

8. **QUESTION:** Can the Chicago Diversion be increased and/or the Long Lake/Ogoki diversions decreased at various times of the year to provide benefits throughout the system?

ANSWER: This is indeed the fundamental purpose and mandate of the study. Knowing that, from the hydraulic point of view, the levels of the Great Lakes can be lowered in this manner, the purpose is to determine what specific diversion changes, if any, could be made that are feasible economically and environmentally. It must be noted, however, that the effects of changing these diversions are not instantly felt throughout the Great Lakes due to the size of the system and the time it takes for changes in the water supply to work down through the system. Prior studies have shown that this can be as long as 15 years. Hence, although small short-range impacts could be obtained in the lake from or into which a diversion is made, the full impacts of flow changes would only accrue if they are sustained over long periods.

LET US KNOW YOUR VIEWS!

Diversions is published by the International Great Lakes Diversions and Consumptive Uses Study Board.

You are encouraged to let us know your concerns and questions about this study by contacting us by mail or telephone. Also, please help us keep our mailing list up to date by notifying us of any change of address.

Address correspondence to the International Great Lakes Diversions and Consumptive Uses Study Board c/o Public Affairs Office, U.S. Army Corps of Engineers, Box 1027, Detroit, Michigan 48231, or c/o Department of Environment, Inland Waters Directorate, Ottawa, Ontario, K1A 0E7, or call (313) 226-4680 in Detroit or (613) 997-1780 in Ottawa.

Thank you for your interest!

Diversions

ÉTUDE INTERNATIONALE DES DÉRIVATIONS ET DES UTILISATIONS CONSOMMATRICES DE L'EAU DES GRANDS LACS

Nº 2 • JUIN 1979

21% DE RÉPONSES À NOTRE FORMULAIRE

La première édition de **Diversions**, qui a été préparée par le Bureau international d'étude sur les dérivations et les utilisations consommatrices de l'eau des Grands lacs, s'est avérée fructueuse et nous voulons profiter de l'occasion pour remercier tous ceux et celles qui ont répondu à notre appel visant la connaissance des points de vue et intérêts publics.

Des 14,500 bulletins adressés à divers intérêts publics dans la région du bassin des Grands lacs, 21 pour cent ou 3,100 personnes ont répondu à l'enquête en nous faisant part de leurs intérêts sur cette étude et sur l'établissement d'ateliers de travail.

Nous regrettons que certaines personnes ont reçu l'édition après la date limite de réponse et que les enveloppes de réponse pré-adressées n'ont pas été insérées dans toutes les publications. Nous voulons particulièrement remercier ceux et celles qui nous ont retourné quand même leur formulaire dûment rempli.

Les répondants ont été séparés en groupes pour représenter les catégories suivantes: membres non affiliés du public, y compris plusieurs propriétaires riverains, 63 pour cent des répondants; représentants du gouvernement à tous les niveaux, 13 pour cent; représentants de l'industrie, 8 pour cent; la gent académique, 8 pour cent; les groupes représentant des intérêts spéciaux, y compris les groupes environnementaux et les associations riveraines, 7 pour cent; et la presse, 1 pour cent.

La question de propriété riveraine a engendré le plus grand nombre de réponses; 57 pour cent des répondants ont manifesté leurs inquiétudes par rapport aux droits de propriété riveraine et aux problèmes découlant de l'érosion et des inondations. La récréation est venue en deuxième rang. L'ordre respectif de priorité des autres sujets est le suivant: pêche et vie sauvage, navigation, utilisations consommatrices, intérêts politiques et énergie hydro-électrique.

Nous regrettons de ne pas pouvoir répondre personnellement à toutes les questions et tous les commentaires formulés. Par contre, les questions et commentaires les plus usités paraissent aux pages 3 et 4 de la présente édition de **Diversions**. Plusieurs demandes à caractère technique ont fait l'objet de réponses individuelles.

De tous les répondants, 75 pour cent ont manifesté le désir d'assister à au moins un atelier de travail sur la présente étude. Même si les personnes intéressées représentaient la région entière des Grands lacs, le plus grand nombre de réponses se concentrait dans les trois secteurs de Chicago, Détroit-Windsor et Buffalo-Toronto.

Des ateliers de travail s'adressant au public sont prévus à titre d'essai dans ces trois localités et dans au moins un secteur du bassin du lac Supérieur. Nous nous attendons à ce qu'ils soient tenus au printemps 1980. Le comité d'étude responsable des ateliers se penchera sur les sujets de discussion suivants: les effets hydrologiques et économiques de la production d'énergie, de la navigation et des intérêts riverains. Les dates de tenue des ateliers paraî-

Les membres du personnel du Bureau d'affaires publiques du «U.S. Army Corps of Engineers» à Détroit (Michigan) effectuent une révision des enquêtes de **Diversions** en compilant les réponses des membres du public. Plus de 3,100 formulaires ont été reçus et compilées.

tront dans la troisième publication de **Diversions** et seront annoncées publiquement par la presse locale.

De plus, nous accepterons les commentaires écrits des membres du public qui ne pourront pas assister aux ateliers en raison de problèmes de distance ou de facteurs analogues. Vos connaissances comme membres du public intéressé constituent un facteur important dans l'avancement et les résultats de l'étude en cours et tous les points de vue abordés seront considérés à même le contexte englobant l'étude.

Se reporter à la page 4 pour retrouver les adresses de correspondance applicables.

FAITS SAILLANTS DANS L'AVANCEMENT DES ÉTUDES

Options de dérivation

Des études sur l'évaluation des impacts se poursuivent pour établir toutes les combinaisons possibles des options de dérivation énumérées dans la première publication. (Ces options sont répétées ci-après.) Au cours de ces études, une évaluation détaillée des conditions dans le chenal Illinois (dérivation à Chicago[1]) a indiqué que la possibilité d'augmenter les débits au-dessus du taux actuel de 3,200 pi^3/s avait été sous-estimée. Une ré-évaluation des conditions a entraîné une augmentation de cette valeur à un débit annuel moyen d'environ 8,700 pi^3/s au lieu des 8,100 pi^3/s antérieurement reportés.

(1) Dérivations lac Long/Ogoki – Les valeurs de 5,000, 2,500 et 0 pi^3/s feront l'objet d'une évaluation.

(2) Dérivation du lac Michigan à Chicago[1] – Une partie de cette dérivation pourrait aussi être fermée, mais la valeur de 0 pi^3/s n'est pas tout à fait pratique puisque la consommation domestique et la navigation dans le secteur doivent être satisfaites; toutefois, comme point de référence, on évaluera aussi 0 pi^3/s. Par conséquent, les débits annuels moyens de 0, 3,200 (moyenne actuelle), 6,600 et 8,700 pi^3/s feront aussi l'objet d'une évaluation.

(3) Canal Welland – Une partie de cette dérivation pourrait aussi être fermée, mais le chiffre 0 ne serait pas pratique vu les besoins de la navigation entre les lacs Érié et Ontario et de la production d'énergie. La décharge moyenne actuelle par le canal est de 7,000 pi^3/s, mais sa capacité moyenne sur une base annuelle est de 9,000 pi^3/s. Ces deux valeurs seront donc évaluées ainsi que 0 comme point de référence.

Ces dérivations seront évaluées individuellement et en combinaisons.

Chaque option individuelle ou combinée sera évaluée au moyen de paramètres représentatifs afin de déterminer les moments propices aux réglages des débits. Les paramètres considérés sont les niveaux des lacs, l'apport d'eau au système et (ou) la prévision des conditions extrêmes dans l'apport d'eau.

Utilisations consommatrices

On a établi des projections préliminaires sur les utilisations consommatrices dans le système jusqu'à l'année 2035. Ces projections représentent une réduction progressive dans l'utilisation de l'eau qui traversera les lacs dans le futur. La compilation des effets des taux de consommation sur les niveaux d'eau des lacs est rendue possible en «débitant»[2] les taux projetés d'alimentation réduite dans le système, ce qui permet d'évaluer leurs impacts économiques.

Évaluation environnementale

Les études sur l'évaluation environnementale se concentrent sur les trois régions suivantes: le système des Grands lacs et du St-Laurent pris comme un tout, le chenal Illinois et les dérivations des réservoirs Ogoki et du lac Long. Les ressources budgétaires et de main-d'oeuvre du Comité font face à toutes sortes de restrictions et le développement des études sur l'évaluation environnementale sera régi par les impacts économiques des différentes options considérées. En d'autres termes, toute option qu'il faut abandonner parce qu'elle ne s'avère pas rentable du point de vue économique ne justifierait pas la dépense de ces ressources par rapport à la détermination de ses impacts sur l'environnement.

Participation du public

L'enquête menée par suite de la publication de **Diversions** de novembre 1978 pour déterminer la participation du public a donné une réponse satisfaisante. Les questions les plus fréquemment posées sont répondues dans la présente édition. Nous espérons tenir des ateliers de travail s'adressant au public et englobant les résultats des études abordées au printemps 1980.

[1] Dérivation du lac Michigan à Chicago, reportée ci-après comme dérivation à Chicago.

[2] Le terme «débitant» correspond à un calcul hydraulique où les changements dans les débits d'entrée, d'écoulement intérieur et de sortie du système des Grands lacs, de corps avec d'autres facteurs comme la précipitation et l'évaporation sont convertis en changements dans les niveaux d'eau des lacs.

RÉPONSES À VOS QUESTIONS

1. **Question**: Pourquoi la présente étude se limite-t-elle à l'analyse des principales dérivations actuelles? Comment la modification des débits actuels de ces dérivations pourrait-elle affecter le système des Grand lacs?

Réponse: Les limites de l'étude sont définies dans la Référence des deux gouvernements dont la date de publication remonte au 21 février 1977. Cette Référence proposait qu'une étude soit entreprise pour examiner la rentabilité de modification des dérivations approuvées existantes et (ou) proposées à même, se jetant dans ou sortant du bassin des Grands lacs. Même si cette étude ne se limite pas aux dérivations majeures existantes, des études antérieures sur le système des Grands lacs ont indiqué que seules les dérivations majeures des réservoirs Ogoki et du lac Long, du canal Welland et de Chicago étaient assez grandes pour causer des impacts importants sur les débits et niveaux d'eau du système. La phase initiale de l'étude s'est donc concentrée sur les plans d'aménagement de ces dérivations; toutes les dérivations mineures comme celle du canal Barge dans l'état de New York seront étudiées dans une phase ultérieure.

La deuxième partie de la question ci-haute porte sur la raison de l'étude. Des études antérieures ont partiellement abordé l'effet de modification de ces dérivations sur le plan hydrologique. La présente étude englobera tous les points de vue en ne se limitant pas seulement à l'impact hydrologique, mais en abordant aussi les impacts économiques et les effets généraux sur l'environnement. On est actuellement en train d'évaluer ces impacts.

2. **Question**: Est-ce que la présente étude tient compte des changements physiques dans le système des Grands lacs?

Réponse: La Référence ne tient pas compte de l'étude des changements physiques dans le système des Grands lacs. L'étude porte essentiellement sur les canaux de dérivation existants et leurs capacités physiques. Les sujets comme l'approfondissement des canaux et la dérivation proposée du canal Black Rock le long de la rivière Niagara sont actuellement soumis à l'Étude de contrôle du lac Érié sous une autre référence. Les données découlant de ces deux études sont échangées par les organismes responsables qui en assurent la coordination.

3. **Question**: Pourquoi la présente étude a-t-elle été entreprise alors qu'une étude antérieure par le Bureau international des niveaux des Grands lacs avait déjà été complétée?

Réponse: L'étude du Bureau international des niveaux des Grands lacs (BINGL) portait sur les différents facteurs pouvant affecter la fluctuation des niveaux d'eau et sur les mesures à prendre pour assurer une meilleure utilisation du système des Grands lacs. Aux fins de cette étude, les taux de dérivation utilisés étaient fixes. Ces taux ont fait l'objet d'une autorisation légale ou d'un accord fondé sur des échanges de Notes entre les gouvernements américain et canadien. Alors que le rapport définitif du Bureau des niveaux des Grands lacs présentait les impacts des dérivations existantes soumises à des taux fixes, les impacts de contrôle des dérivations n'avaient fait l'objet d'aucune recherche puisqu'ils ne faisaient pas partie des thèmes abordés. Par conséquent, le BINGL a recommandé que ces impacts soient compris dans une étude séparée. L'Étude des dérivations et des utilisations consommatrices a donc été proposée par les deux gouvernements.

4. **Question**: Quels étaient les critères pour déterminer la sélection des participants du Bureau d'étude?

Réponse: La sélection des participants aux études des Bureaux de la CMI s'effectue sur une base de consultation entre la CMI et les gouvernements fédéraux, provinciaux et d'états. Dans le présent cas, les Références du lac Érié et des Dérivations et utilisations consommatrices se concentraient sur la même région géographique et les membres de chaque Bureau ont été choisis pour représenter la région où le plus grand impact devait se faire sentir par rapport à l'étude particulière. La CMI a demandé aux deux Bureaux de garder un rapport étroit entre eux et d'établir un système assurant un libre échange de renseignements.

5. **Question**: Qu'est-ce qui cause les fluctuations dans les niveaux d'eau? De tels changements peuvent-ils être contrôlés au bénéfice des différents intérêts impliqués dans le bassin des Grands lacs? Jusqu'à quel point peut-on rendre le niveau moyen plus constant?

Réponse: Ces questions fondamentales ont été examinées en détail par le BINGL (1964-73) et l'étude en cause ne sera pas reprise par le présent Bureau. En principe, les niveaux d'eau des lacs s'élèvent et s'abaissent sur une base saisonnière, dépendant du cycle hydrologique annuel. Sur une base à plus long terme, la variation dans les niveaux d'eau dépend des périodes prolongées de sécheresse ou d'humidité au cours des années. Par exemple, l'augmentation des précipitations entraîne une hausse des niveaux; des niveaux plus élevés rehaussent les débits de sortie; des débits plus grands assurent une diminution des niveaux. D'un autre côté, les niveaux des lacs commencent à descendre durant les périodes où les précipitations sont faibles, ce qui entraîne une diminution des débits de sortie et une stabilisation des niveaux. Ceci veut dire que les lacs s'autorégularisent naturellement lorsqu'ils ne subissent pas l'influence de l'homme. Par contre, les régimes naturels des débits de sortie et des niveaux des lacs Supérieur et Ontario sont modifiés par les ouvrages de régularisation construits à l'emplacement de leurs sorties (à Sault-Sainte-Marie et à Cornwall/Massena respectivement). Ces travaux et les installations connexes de navigation et de production d'énergie servent à contrôler les débits de sortie et influencent donc les niveaux d'eau des lacs. L'étude du BINGL qui essayait de déterminer jusqu'à quel point d'**autres** contrôles des débits de sortie des lacs seraient rentables est arrivée aux 3 conclusions suivantes: (i) les niveaux d'eau du lac Supérieur pouvaient être améliorés en modifiant le plan d'opération des installations du lac, une telle modification représentait nettement des avantages pour les usagers; (ii) le contrôle des lacs Michigan/Huron par la construction d'ouvrages à la sortie des rivières Sainte-Claire/Détroit n'était pas rentable du point de vue économique; (iii) le contrôle du lac Érié par la construction de travaux à sa sortie offrait certaines possibilités. Suite à cette étude, la CMI a exigé qu'un nouveau plan d'opération pour le contrôle du lac Supérieur soit préparé par le Comité de contrôle du lac Supérieur et le Bureau international d'étude sur le contrôle du lac Érié a été créé pour étudier plus à fond le contrôle de ce lac. La CMI a aussi fondé le Bureau international d'étude sur les dérivations et les utilisations consommatrices qui tente, entre autres, de déterminer si les régimes des niveaux des lacs peuvent être améliorés en modifiant n'importe laquelle des dérivations d'entrée ou de sortie du bassin des Grands lacs.

6. **Question:** L'étude en cours tient-elle compte de certains facteurs comme l'écoulement de l'eau des rivières affluentes et des terres dans les lacs, la précipitation, l'évaporation et l'évapo-transpiration, l'eau utilisée dans les installations de production d'énergie et ainsi de suite? Peut-on évaluer de tels facteurs à l'ordinateur?

Réponse: Oui. Tous ces facteurs (et plusieurs autres) sont compris dans les calculs hydrologiques, hydrauliques et économiques impliqués. La technique actuelle nous oblige à évaluer ces facteurs à l'ordinateur.

7. **Question:** Qu'entend-on par dérivations Ogoki/lac Long? Seront-elles accrues? Est-il réaliste de penser à les réduire à zéro?

Réponse: Ces dérivations transportent de l'eau dans le lac Supérieur à partir de rivières qui s'écoulaient originalement en direction nord-est, dans le système de la rivière Albany et enfin, dans la baie James. En existence depuis environ quarante ans, lesdites dérivations servent au transport des billots et à la production d'énergie hydro-électrique. La réduction de ces dérivations à zéro durant les périodes où les Grands lacs sont fortement alimentés s'avère physiquement possible, mais les coûts de remplacement de l'énergie perdue et d'utilisation d'un système alternatif de transport des billots doivent être considérés lors de l'établissement du solde des pertes et bénéfices économiques résultant d'une telle modification dans le système des Grands lacs. Réciproquement, la possibilité d'augmentation des dérivations durant les périodes où l'alimentation des Grands lacs est réduite a aussi été considérée. Aucune augmentation dans le taux de dérivation n'est possible parce que les dérivations actuelles sont alimentées par toute l'eau disponible et soumises aux restrictions d'opération des lacs Nipigon et Long.

8. **Question:** La dérivation à Chicago peut-elle être accrue et les dérivations Ogoki/lac Long peuvent-elles être réduites à différents moments de l'année pour augmenter la rentabilité du système?

Réponse: Ceci constitue en fait le mandat et l'objet fondamental de la présente étude. En sachant que les niveaux d'eau des Grands lacs peuvent être abaissés du point de vue hydraulique, il faut alors déterminer quels changements de dérivation spécifiques, s'il y a lieu, peuvent être effectués toujours en demeurant rentables sur les plans économique et environnemental. À noter cependant que les effets de changement de ces dérivations ne se font pas immédiatement sentir dans les Grands lacs; une des raisons est l'immensité du système et l'autre, le temps requis pour que des changements dans l'alimentation d'eau se manifestent à même le système. Des études antérieures ont démontré que la réalisation des changements peut prendre jusqu'à 15 ans. Même si de petits impacts à court terme pouvaient être réalisés dans le lac à partir duquel ou vers lequel la dérivation est effectuée, il n'en reste pas moins que les impacts complets des changements dans les débits ne seraient concrétisés que si de tels changements étaient maintenus pendant de longues périodes.

DONNEZ–NOUS VOTRE POINT DE VUE!

«Diversions» est publié par le Bureau international d'étude sur les dérivations et utilisations consommatrices de l'eau des Grands lacs.

Nous vous encourageons à nous faire part de vos commentaires et questions sur la présente étude en communiquant avec nous par téléphone ou courrier. Prière de nous aider à garder notre liste d'envoi à date en nous avisant de tout changement d'adresse.

Prière aussi d'adresser toute la correspondance au Bureau international d'étude sur les dérivations et utilisations consommatrices de l'eau des Grands lacs, c/o Public Affairs Office, U.S. Army Corps of Engineers, Box 1027, Detroit, Michigan 48231 ou a/s du Ministère de l'Environnement, Direction générale des eaux intérieures, Ottawa (Ontario) K1A 0H7. Les communications téléphoniques s'effectuent en composant le numéro (313) 226-4680 pour Détroit ou (613) 997-1780 pour Ottawa.

Nous vous remercions de votre intérêt!

Diversions

INTERNATIONAL GREAT LAKES DIVERSIONS AND CONSUMPTIVE USES STUDY
NO. 3 • April 1980

Study progress will be presented at upcoming public workshops

Preliminary results emerging from the International Great Lakes Diversions and Consumptive Uses study will be presented to interested parties in May 1980 at a series of public workshops in Chicago, Buffalo, and Detroit, U.S.A., and in Toronto and Sault Ste. Marie, Ontario, Canada.

The meetings will provide an opportunity for people not directly involved in the study to familiarize themselves with the subjects being studied as well as with the progress to date, and to express their views.

Background

The International Great Lakes Diversions and Consumptive Uses Study Board was established in 1977 to undertake a study of the diversions and consumptive uses in the Great Lakes Basin and their effects on water levels and flows in the Great Lakes.

Previous investigations of Great Lakes levels have not included a consideration of the impacts or benefits which might be derived from possible alternative methods of managing the Basin's diversions. These diversions are man-made alterations to the water supplies of the Great Lakes; i.e., altering the flows into, out of, or between the Great Lakes.

The major diversions being considered in this study are the Long Lake/Ogoki Diversions into Lake Superior, the Lake Michigan Diversion at Chicago, and the Welland Canal Diversion out of Lake Erie. Also, previous investigations have not examined the effects of consumptive uses of water, such as agricultural, manufacturing, and domestic uses, on lake levels and flows.

Therefore, in 1977, the governments of the United States and Canada directed the International Joint Commission—an agency which considers boundary water problems common to the interests of both governments—to investigate these two subjects. The Commission, in turn, appointed experts from both countries to the Study Board.

The Study Board is presently scheduled to report its findings to the International Joint Commission in the summer of 1981. The Board's report will identify one or more diversion management scenarios and outline the range of likely impacts on the major interests to be affected (shore property, navigation and power). Projections of consumptive uses on the Great Lakes to the year 2035, and the attendant impacts on these interests, will also be presented.

Public Workshops

The dates and locations of the workshops are given below. The locations were selected according to the response from an earlier questionnaire.

(Continued on page 2)

Schedule of Public Workshops

May 14, 1980 — Sault College of Applied Arts & Technologies, Sault Ste. Marie, Ontario, Canada

May 15, 1980 — Windsor Hotel near O'Hare Airport, Chicago, Ill., U.S.A.

May 20, 1980 — Downtown Statler Hotel, Buffalo, N.Y., U.S.A.

May 21, 1980 — Toronto Public Library, 789 Yonge St., Toronto, Ontario, Canada

May 22, 1980 — Southfield Sheraton, Detroit, Mich., U.S.A.

Important — If a lack of interest on the part of the public is displayed—that is, if minimal response to any one of the planned workshops is indicated through the enclosed questionnaire—that particular meeting will be cancelled. If a workshop is cancelled, you will be notified, and we will be pleased to meet individually or to correspond with those who had wished to attend.

(Continued from page 1)

At the upcoming public workshops, the Study Board will report on the progress to date. The main scenarios being considered and their hydrologic and environmental implications will be presented, as well as the projected consumptive uses and their hydrologic effects. The evaluation methodology by which findings are reached will be discussed.

Following this opening review, those in attendance will have an opportunity to present statements and voice opinions. This segment will be followed by a question-and-answer period and general discussion. If the group is large and various individuals have specific concerns, the meeting will be broken up into smaller groups, where they will be able to meet with those who are knowledgeable in their areas of concern.

The moderator will close by reviewing the main points developed in the workshop. Afterward, participants will have an opportunity to evaluate the workshop by means of questionnaires.

Methodology

Essentially, the study has two tasks: the first, to study the effects of existing diversions, and how these effects would change if the diversions were managed in a different manner; the second, to quantify existing consumptive uses, estimate how these will increase in the future, and examine their hydrologic effects.

Basis of Comparison. The first step in determining how past human intervention affects present Great Lakes levels and flows has been the establishment of a Basis of Comparison. This is a baseline water regime against which possible changes due to such further intervention can be measured and evaluated.

Because of the many physical and regulatory changes that have occurred in the Great Lakes system over the years, it is impractical to use historical levels and flows for this purpose. Instead, the Basis of Comparison consists of a series of levels and flows obtained by using, via a computerized model, the actual water supplies recorded during the period of 1900-1976, assuming contemporary physical conditions to have existed and current regulation plans to have been in operation constantly throughout the period.

Specifically, the Basis of Comparison assumes seven constant features, namely: Lake Superior regulated in accordance with Plan 1977; Lake Ontario regulated in accordance with Plan 1958D; average diversions of 5,000 cubic feet per second at Long Lake/Ogoki, 3,200 cfs at Chicago, and 7,000 cfs at the Welland, and present channel conditions in the St. Clair-Detroit and Niagara Rivers.

Diversion Trigger. The study procedure assumes that if, at times of high water supplies and correspondingly high lake levels, the Long Lake/Ogoki diversions were cut back (reducing flow into the Great Lakes) and/or the Chicago diversion was stepped up (increasing flow from the Great Lakes), there would be some alleviation of high lake levels. To explore the numerous possibilities, it had to be determined when, and by how much, diversion flows might be changed. Two types of triggers were studied—lake stage and water supply. The latter was found more effective, because supply changes precede level changes and thus give more lead time. When the water supply goes

Niagara Falls

above the long-term mean value, the diversion flow changes being tested are triggered.

Insofar as the "how much" is concerned, diversion changes were selected which bracket the range of possibilities. For the Welland Canal, an increase to its maximum capacity of 9,000 cfs was considered. For the Chicago diversion, consideration was given to a maximum annual case of 8,700 cfs and an intermediate case of 6,600 cfs. For the Long Lake/Ogoki diversions, two alternatives were considered: a maximum change; i.e., triggering a complete shutdown of the diversions to zero, and an intermediate case; i.e., triggering down to 2,500 cfs. These and other diversions changes, singularly and in various combinations, give 39 scenarios for evaluation.

Projecting Consumptive Uses. From a base year of 1975, a "Most Likely Projection" has been developed as the best estimate of the withdrawal and consumption of water over the next six decades, to the year 2035. Sectors of water use considered in this study are: municipal, rural-domestic, rural-stock, manufacturing, power generation, irrigation and mining. At least 90% of all projected water consumption is attributed to three of these seven sectors—municipal, manufacturing and power generation. While varying considerably between water-use sectors and specific areas within the Great Lakes, consumptive water use on a total basin scale remains a relatively constant 6-7% of water withdrawals.

Forecasts depend upon the assumptions made. A number of "alternative" futures have been prepared by varying the basic assumptions. They were developed to indicate the inherent uncertainties in forecasting changes and new developments in the economic, technologic and public policy spheres, and the possibility of unexpected large scale catastrophic events. With this in mind, the "Most

Likely Projection" and its alternatives provide the best estimates of consumptive water-use trends in the Great Lakes Basin for input to the analysis of impacts on lake levels.

The hydrologic analysis of consumptive uses essentially involves determining the difference between Basis of Comparison levels and flows and those obtained when the steadily-increasing estimated future consumptive uses are introduced into the computations. It should be noted that future consumption uses will not only ameliorate extreme high lake levels, but will make diversion management increasingly ineffective, since reduced supplies will less frequently trigger diversion changes.

Major Interests Affected. There are several areas of impacts being evaluated in the overall study. The effects on shoreline property (primarily flooding and erosion), marine structures and water intakes are being examined. The basic components of this examination are available flood damage, water level and physiographic data.

The effect on commercial navigation, power production, recreational opportunities, and commercial fishery activities is also being examined. As the lake level is lowered, the capability for a ship to load to its maximum is reduced, resulting in fewer tons of commerce cargo per trip. This, along with alternate modes of transportation competing with water-borne commerce, would have a negative economic impact on ports and local communities. The loss or gain of hydro-electric power production is based upon the cost of power. The cost may vary greatly, depending upon the availability of power and the nature of the power system affected.

Changes in beach areas are being evaluated in terms of their ability to provide recreational opportunities. Recreational boating and commercial fishery activities may be affected if lake levels became too low to navigate. The monetary value of this impact is based upon the percent of time during the boating season that the various types of boats could not operate, or upon the cost of dredging required to offset the lowered lake levels.

Lake level alterations due to diversion management could result in adverse or beneficial impacts on Great Lakes water quality, wildlife and fish. The emphasis on the water quality evaluation is on the near-shore area, since water level fluctuations, as well as water quality impacts, would be most noticeable in shallower water, where most water-related activities and uses occur.

The major effects on wildlife are through changes in wetland areas. Evaluation is with respect to effects on wetland types, long-term and short-term vegetation structure, and wildlife habitat. Effects on fish are being evaluated through the review of published reports. Strong emphasis was placed on identifying the requirements of the fish populations for specific near-shore habitat, especially wetlands and shallow embayments, and identifying the fish species which require, in summer, the cool waters of the hypolimnion.

Progress

As described above, the major components of the study are the determination of the hydrologic, economic, and environmental impacts on the Great Lakes system of diversions and consumptive uses

Diversions and Environmental Investigations. The hydrologic computation for assessing the effects of varying the rates of existing diversions (within their present physical capacities) during periods of above-average supply have been completed for 39 scenarios. From this total array, the Board has selected the following seven scenarios for detailed evaluation:

1.	Long Lake/Ogoki Diversions	0
	Chicago Diversion	3,200 cfs
	Welland Canal	7,000 cfs
2.	Long Lake/Ogoki Diversions	5,000 cfs
	Chicago Diversion	3,200 cfs
	Welland Canal	9,000 cfs
3.	Long Lake/Ogoki Diversions	5,000 cfs
	Chicago Diversion	8,700 cfs
	Welland Canal	7,000 cfs
4.	Long Lake/Ogoki Diversions	0
	Chicago Diversion	8,700 cfs
	Welland Canal	9,000 cfs
5.	Long Lake/Ogoki Diversions	0
	Chicago Diversion	0
	Welland Canal	0
6.	Long Lake/Ogoki Diversions	5,000 cfs
	Chicago Diversion	0
	Welland Canal	7,000
7.	Long Lake/Ogoki Diversions	5,000 cfs
	Chicago Diversion	3,200 cfs
	Welland Canal	0

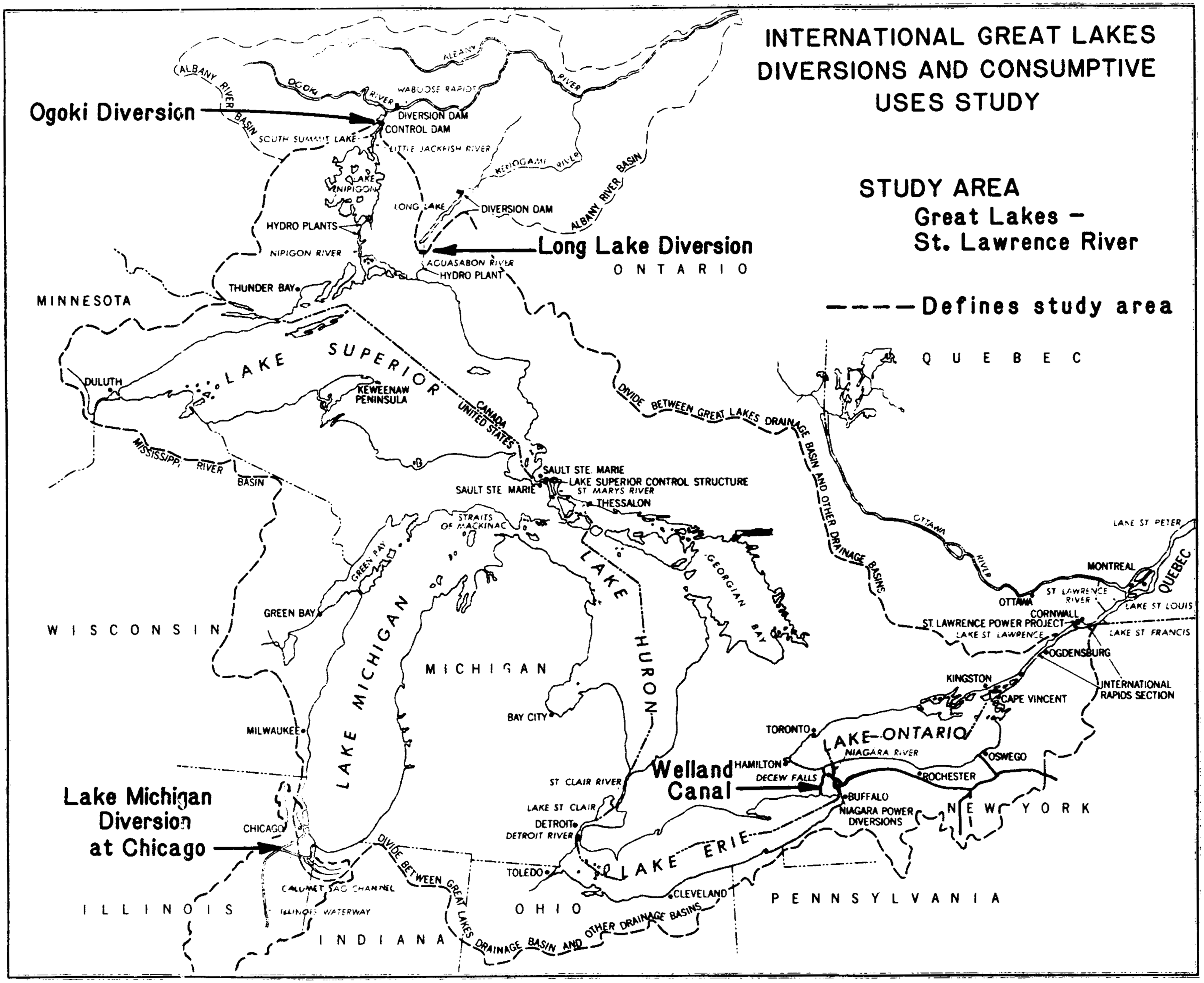
The hydrologic investigations conducted to date indicate that scenario (4) has the greatest impact on lake levels. On Lakes Michigan-Huron, the maximum level would be lowered by approximately 7", the minimum level by 2", and the mean level by 4". It was found that the environmental effect of this scenario would be minor, based on the available data.

An environmental assessment of impacts on the Long Lake/Ogoki diversions system was precluded by a lack of data for this area. With respect to the Lake Michigan Diversion at Chicago, an environmental assessment report concerning the area adjacent to the Illinois Waterway was completed in November 1979. Data from the report indicates that incremented diversions will have only nominal effects on biological resources, due to various constraints in the diversion operating plan.

The balance of the environmental evaluation; i.e., the impact on beaches, boating and water quality, is being conducted by the International Lake Erie Regulation Study Board. Preliminary findings are expected to be available at the upcoming workshops.

Consumptive Uses Investigations. The consumptive uses element of the study has been essentially completed. From the base year 1975 to 2035, a "Most Likely Projection" has been developed as the best estimate of withdrawal and consumptive water use over the next 60-year period. Under this projection, the total water consumption in the Great Lakes Basin is expected to increase from 4900 cubic feet per second in 1975 to 25,000 cfs in 2035.

Evaluation of the hydrologic effects of increasing consumptive uses includes the determination of the point at which the current regulation plans for Lakes Superior and Ontario may become totally impractical, due to the lowered levels of the lakes caused by the increased consumptive use.


INTERNATIONAL GREAT LAKES DIVERSIONS AND CONSUMPTIVE USES STUDY
STUDY AREA
Great Lakes – St. Lawrence River
– – – – Defines study area
Ogoki Diversion
Long Lake Diversion
Lake Michigan Diversion at Chicago
Welland Canal
ALBANY RIVER BASIN
ALBANY RIVER
OGOKI RIVER
WABOOSE RAPIDS
DIVERSION DAM
CONTROL DAM
SOUTH SUMMIT LAKE
LITTLE JACKFISH RIVER
KENOGAMI RIVER
LAKE NIPIGON
LONG LAKE
DIVERSION DAM
HYDRO PLANTS
NIPIGON RIVER
AGUASABON RIVER
HYDRO PLANT
THUNDER BAY
ONTARIO
MINNESOTA
QUEBEC
LAKE SUPERIOR
DULUTH
KEWEENAW PENINSULA
CANADA
UNITED STATES
MISSISSIPPI RIVER BASIN
DIVIDE BETWEEN GREAT LAKES DRAINAGE BASIN AND OTHER DRAINAGE BASINS
SAULT STE. MARIE
SAULT STE. MARIE
LAKE SUPERIOR CONTROL STRUCTURE
ST MARYS RIVER
THESSALON
STRAITS OF MACKINAC
GREEN BAY
GREEN BAY
GEORGIAN BAY
LAKE HURON
OTTAWA RIVER
LAKE ST PETER
MONTREAL
QUEBEC
OTTAWA
ST LAWRENCE RIVER
LAKE ST LOUIS
CORNWALL
ST LAWRENCE POWER PROJECT
LAKE ST LAWRENCE
LAKE ST FRANCIS
OGDENSBURG
INTERNATIONAL RAPIDS SECTION
KINGSTON
CAPE VINCENT
WISCONSIN
LAKE MICHIGAN
MICHIGAN
BAY CITY
MILWAUKEE
TORONTO
LAKE ONTARIO
NIAGARA RIVER
OSWEGO
HAMILTON
DECEW FALLS
ROCHESTER
BUFFALO
NIAGARA POWER DIVERSIONS
NEW YORK
ST CLAIR RIVER
LAKE ST CLAIR
DETROIT
DETROIT RIVER
CHICAGO
LAKE ERIE
TOLEDO
CLEVELAND
CALUMET SAG CHANNEL
ILLINOIS WATERWAY
ILLINOIS
INDIANA
OHIO
PENNSYLVANIA

Public Workshops

Questionnaire

1. Which of the public workshops do you plan to attend?

___Sault College of Applied Arts & Technologies,
Sault Ste. Marie, Ontario, Canada
May 14, 1980

___Windsor Hotel near O'Hare Airport,
Chicago, Ill., U.S.A.
May 15, 1980

___Downtown Statler Hotel,
Buffalo, N.Y., U.S.A.
May 20, 1980

___Toronto Public Library,
789 Yonge St.,
Toronto, Canada
May 21, 1980

___Southfield Sheraton,
Detroit, Mich., U.S.A.
May 22, 1980

2. Do you prefer an afternoon or evening meeting?

___afternoon
___evening

3. Do you plan on presenting a statement at the workshops?

___Yes
___No

4. What is your interest regarding the study? (Check one or more:)

___Water level control
___Shore property — On which lake? ____________
___Navigation
___Hydro-electric power
___Fish and wildlife
___Recreation
___Political concern
___Special interest group or agency — Please name: ____________
___Other: ____________

5. If you cannot attend a workshop, we would be pleased to accept your concerns, questions, etc., by mail. The deadline for receiving information of this type is July 1, 1980.

For follow-up purposes, please provide:

Name ____________

Address ____________

____

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please tape or staple here

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FROM: ______________________

PLACE
STAMP
HERE

TO: **INTERNATIONAL GREAT LAKES DIVERSIONS AND CONSUMPTIVE USES STUDY**
c/o Inland Waters Directorate
Environment Canada
Ottawa, Ontario K1A 0E7

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Diversions

INTERNATIONAL GREAT LAKES DIVERSIONS
AND CONSUMPTIVE USES STUDY

No. 4. SEPTEMBER 1980

PUBLIC WORKSHOPS HIGHLIGHTED CONCERNS OF SHORELINE RESIDENTS

In May 1980, the International Great Lakes Diversions and Consumptive Uses Study Board presented preliminary findings to interested parties at a series of workshops.

A total of 117 people attended the six workshops: 7 at Sault Ste. Marie, Ontario; 14 at Chicago, Illinois; 22 at Buffalo, New York; 10 at Toronto, Ontario; and 64 at the two workshops at Detroit, Michigan. The workshops were held on May 14, 15, 20, 21 and 22 respectively.

The major concern of participants at all workshops was the future status of shore property. Other areas of concern included recreation and fish and wildlife followed by hydroelectric power, consumptive use and navigation.

The main theme heard throughout the workshop was that water levels in the Great Lakes system seem to be managed for the benefit of navigation and hydroelectric power interests. Furthermore, it was noted that the water levels preferred by these entities are in direct conflict with the preferences of riparian interests. The Board was asked to bear in mind while carrying out its evaluations that business losses that may be suffered by shipping and power interests are replaceable or recoverable while shoreline losses are forever. See the editorial on page 3 for the Board's view.

WORKSHOP FORMAT

Workshop locations and times had been scheduled in accordance with public preferences as expressed in questionnaires distributed via earlier issues of **Diversions**.

Each workshop began with an introduction of workshop principals by the moderator - Col. Bob Vermillion in the United States and Mr. John Bathurst in Canada, the co-chairmen of the Study Board's Working Committee.

The introduction was followed by a half hour slide-illustrated presentation which reviewed in greater detail the material outlined in the third issue of **Diversions**. This included the main diversion management scenarios being considered by the Board and their hydrologic and environmental implications, the projected trends in consumptive use and associated hydrologic effects and the methodology being used to evaluate selected diversion management scenarios.

As an example of the type of data presented for public review and comment, see the table on the next page, which shows the hydrologic impacts of four diversion management scenarios on the Great Lakes System.

After the presentation by the Board, those in attendance had an opportunity to present statements. A general discussion period followed. At the end of each workshop, participants were invited to evaluate their experience by means of questionnaires. A short summary on each workshop is presented on the following pages.

WORKSHOP HIGHLIGHTS

Sault Ste. Marie, Ontario - May 14, 1980

The workshop was attended by interested residents from the surrounding area including a representative of the Whitefish Bay Shore Erosion Association. Although the

A Note of Appreciation

To all those who attended the May workshops held by the International Great Lakes Diversions and Consumptive Uses Study Board, thank you for your time, your effort and your contributions.

Limited space makes it impossible to note in the Newsletter all the questions and concerns that were expressed at the five workshops. Nonetheless, all input was equally appreciated and will be included by the Board as part of its findings in the final report to the International Joint Commission in May 1981.

We also thank those people who were unable to attend a workshop but took the time to write and express their views.

number of participants was small, a useful exchange of information took place. In particular, discussion centered on the operating range of Lake Superior and the effect of the maximum impact scenario on that lake. (See scenario 4, in the table.) The representative from the Whitefish Bay Association noted that current high levels were destroying sand dunes and associated beach nourishment. The Board was aware of the problem but stated that enormously expensive construction would be required to bring lake levels down. It was not within the present Board's terms of reference to consider additional construction; the Board was to assess the impact of varying existing diversions, i.e., Long Lake/Ogoki, Chicago, and Welland. Participants noted other cases of erosion such as at the City of Tawas, and also expressed concern about the hydrologic impact of projected consumptive uses.

Chicago - May 15, 1980

Workshop participants included representatives from public interest groups such as the Lake Shore Property Owners Association and from agencies such as the Metro Sanitary District of Greater Chicago.

A number of questions were raised including how the Board proposed to assess the costs and benefits for the main scenarios and how navigation, power and shore property interests would be weighed in the final analysis. The economic impact on Chicago of forecast lake level reductions due to consumptive use was questioned, as was how shoreline damage figures were being calculated.

The Board explained that all factors - economic, hydrologic and environmental - will be considered in conducting scenario evaluations. To the extent possible, costs and benefits will be expressed in average annual figures. In some cases, notably, social and environmental impacts, dollar equivalents are not readily available. The final evaluations will be submitted by the Study Board to the International Joint Commission, which in turn will report its recommendations to governments.

In terms of the diversion rates at Chicago, the Board noted that these do not include the consumptive use portion and withdrawal for that purpose would not be restricted. The economic impacts of reduced water supply due to projected consumptive use will not be addressed by the present Study; the task of the Board is to assess the hydrologic impact.

It was noted by participants that shoreline damages seem to increase for successive high water periods. In response it was suggested that this could be attributed to development which takes place in the interim period. The natural absorptive capacity of the basin is constantly being reduced, resulting in faster rates of runoff which lead to earlier peaks and higher water levels.

International Great Lakes Diversions and Consumptive Uses Study - Preliminary Results - Hydrologic Comparison* (lake levels in feet)

	Basis of Comparison†	Scenario 1 LL/O 0 CHI. 3200 WELL. 7000	Scenario 2 LL/O 5000 CHI. 3200 WELL. 9000	Scenario 3 LL/O 5000 CHI. 8700 WELL. 7000	Scenario 4 LL/O 0 CHI. 8700 WELL. 9000
LAKE SUPERIOR ‡					
Mean	600.44	600.36	600.43	600.38	600.29
Max	601.93	601.83	601.93	601.92	601.83
Min	598.69	598.42	598.68	598.60	598.31
Range	3.24	3.41	3.25	3.32	3.52
LAKE MICHIGAN-HURON					
Mean	578.27	578.11	578.25	578.10	577.92
Max	581.15	580.92	581.10	580.86	580.59
Min	575.47	575.39	575.46	575.40	575.31
Range	5.68	5.53	5.64	5.46	5.28
LAKE ERIE					
Mean	570.76	570.65	570.71	570.64	570.48
Max	573.60	573.44	573.50	573.40	573.15
Min	568.09	568.05	568.09	568.05	568.00
Range	5.51	5.39	5.41	5.35	5.15
LAKE ONTARIO ‡					
Mean	244.72	244.64	244.73	244.64	244.55
Max	249.44	248.53	249.44	248.40	248.07
Min	241.56	241.18	241.52	241.19	240.74
Range	7.88	7.35	7.92	7.21	7.33

* This table includes 4 of the 7 diversion management scenarios selected for detailed evaluation. The practicality of detailed evaluations of the other 3 scenarios, listed in the third issue of "Diversions", is being assessed.

† Long Lake/Ogoki - 5000 cfs; Chicago - 3200 cfs; Welland - 7000 cfs.

‡ Lake Superior regulated by Plan 1977 and Lake Ontario regulated by Plan 1958-D.

LL/O = Long Lake/Ogoki; CHI. = Chicago; WELL. = Welland.

Also of interest to participants was how the Chicago diversion rates of 3,200 cfs and 8,700 cfs were established. The 1967 Supreme Court decision that limits the Chicago diversion to its present 3,200 cfs was outlined. Also, the Demonstration Program on the Illinois Waterway was explained. It was noted that the figure of 8,700 cfs is being studied in a hypothetical sense; an actual demonstration will not take place. Environmental consequences downstream, e.g., flooding, erosion, that could be associated with a diversion of 8,700 cfs were noted.

Buffalo – May 20, 1980

Statements were received from representatives of Cleveland Yacht Clubs and the Erie County Shoreline Task Force.

The Yacht Clubs' representative was supportive of high lake levels which curtailed the need for dredging to maintain adequate depths for recreational boating. He noted that dredging costs have increased substantially since open lake dumping has been banned.

The Erie County Shoreline Task Force representative relayed the group's concern about high lake levels and stated that levels are maintained for navigation and power interests at the expense of shore property interests. Concern was also expressed about the amount of material being dredged and removed from the lake and the legality of doing so.

The impact of landfills on lake levels was discussed as well.

Several participants were interested in the history and operation of the Long Lake/Ogoki diversions. These diversions were built to improve log driving operations and to enhance power production. A number of participants felt that these diversions are partly responsible for present-day higher water levels. The Board noted that at the request of the U.S. government, the Ogoki diversion was stopped during the high water period of 1974.

Other questions asked pertained to the status of the Lake Erie Regulation Study, in particular, the Squaw Island Diversions; and why thermal power production was being included as a consumptive use.

Toronto – May 21, 1980

Participants included members from the Shoreland Preservation Association and representatives from various provincial and municipal agencies.

No official statements were received. A significant number of questions were concerned with the consumptive uses portion of the Study.

The Board emphasized that the projections are only a "best estimate" based on a number of assumptions. The variance about this best estimate progressively increases from ± 7% in 1985 to ± 40% by 2035. It was noted by participants that the projected consumptive use rates for Canada and the United States in 2035 are 7,000 cfs and 18,000 cfs respectively. A followup question was concerned with whether this would result in new power-sharing arrangements at St. Lawrence and Niagara plants between Canada and the United States. It was stated that this consideration is beyond the terms of reference for the Board.

EDITORIAL

LAKESHORE PROPERTY, NAVIGATION AND POWER

After closely analyzing the discussions, the questions asked and the general flow of information that took place at the May workshops, it becomes clear that most shore property owners feel that studies like the Great Lakes Diversions and Consumptive Uses tend to work against them and to favor navigation and power over riparian interests.

In setting the record straight, it should be pointed out that both this study and the earlier Lake Levels study were undertaken in response to concerns expressed by riparian interests. Every endeavor is made by federal agencies in both Canada and the United States to approach such studies with a completely objective point of view. The Diversions and Consumptive Uses Study is investigating the environmental, economic, and social effects of possible decisions that may alter the Great Lakes system, to even the smallest degree.

It should be emphasized that we are dealing with a study situation. Webster's Dictionary tells us that to study is to reflect upon, to endeavor to learn all that is possible about a subject or subjects. And in this case, to come up with facts that will help us to understand the problems better in order to seek solutions that will reflect the overall good.

In dealing with regional studies, it is desirable to take a broad view that takes into consideration the length of time involved in consolidating all the information needed. The time factor in particular can prove frustrating to the citizen, since we are dealing, by and large, with situations that may be resolved many years in the future.

It is only human to want problems solved right now, but sometimes we have to wait for long periods. One consolation is that future generations will benefit from the dialogue that is going on today. With your help, we will continue to seek out the best solutions for this vast Great Lakes/St. Lawrence region.

Again related to the consumptive use portion, a question was asked whether the environmental impacts of lake levels lowered by consumptive use had been costed. The Board stated that this had not been done very adequately owing to lack of appropriate data.

One participant wanted to know if the Board was considering dredging of the St. Lawrence as a means of increasing outflows and therefore lowering Lake Ontario. Dredging was not within the terms of reference for the Diversions and Consumptive Uses Study Board. However, the Lake Erie Regulation Board was considering such alternatives.

Detroit – May 22, 1980

A total of ten statements were received at the afternoon and evening workshops. Spokesmen included representatives from the Macomb County Board Commissioners, Wayne County Conservation Association, Michigan Shorelands Preservation Association, League of Women Voters, Lake Erie Advisory Committee, Grandview Beach Association, Inter Lake Yachting Association, among others.

As at the other workshops, participants were mainly concerned about high water levels. Examples of negative impacts, such as restricted land use, erosion, and flooding of private property, loss of wildlife habitat, high water table conditions which increased construction and maintenance costs, poorer water quality, etc., were outlined. There was strong support for management of diversions to benefit shore property interests. It was noted that even a reduction of a few inches would benefit riparian interests. Suggestions to reduce lake levels included shutting off the Long Lake/Ogoki diversions, increasing flow through at Chicago and Welland, opening locks at the Black Rock Ship Canal and building the Squaw Island diversion as suggested in the Lake Levels Board Report 1974. Several participants supported chart datum level as the preferred level for Lake Erie. There was unanimous agreement that action be taken as soon as possible; procrastination costs money, e.g., the recent April flood.

To compensate for navigation and power losses under regulated lower level conditions several solutions were proposed: dredging of deeper navigation channels, higher consumer costs for goods carried by Great Lakes vessels, and consideration of alternate energy sources.

At both Detroit workshops, considerable interest was shown in the history and hydrologic impact of the Long Lake/Ogoki diversions. Most participants favored shutting it down when lake levels were high; however, there was some doubt as to whether Canada would support such an action. Participants were reminded that the Ogoki diversion had been shut down during the high water period in 1974.

The projected trends in consumptive use were questioned as well. The Wayne County Conservation Association stated that they will closely examine the assumptions upon which the projections are based, in particular, the conservation aspects. Also, they were concerned about the impacts a decreased range of level fluctuations would have on natural systems. A similar concern was voiced by the representative from the Great Lakes Fisheries Commission. The Board was advised that damage to near-shore reproductive areas could be extensive.

Further questions at Detroit included inquiries about the Chicago diversion rate of 8,700 cfs, the limiting factor on loading of lake vessels (not to draw more than 27 feet), dredging of Lake St. Clair and whether the outflow of the Detroit River could be controlled, seiche impact, and whether low lake levels would return again as part of the long-term cycle.

WORKSHOP EVALUATION

The evaluation sheets returned to us indicated that the majority of participants gave high marks to the Workshops as a tool for information exchange.

All the participants said they found the workshops to be somewhat informative and the majority rated them as definitely informative. Some people were impressed with the leadership displayed in conducting the workshops and one person noted "This is probably the best and most informative discussion I have attended." However, the same participant noted that the negative aspect is knowing "that it will be many years before levels on Lake Erie are controlled."

As to whether participants felt they had an opportunity to express their views and concerns to the Board, an overwhelming majority indicated satisfaction with the workshops.

WORKSHOP IMPACT

On the basis of public input received at the workshops, the Board concluded that *major* changes in study direction are not required. However, within its terms of reference, the Board has made and will continue to make adjustments in response to public concerns. For example, the workshops have prompted additional hydrologic and economic analysis of diversion management scenarios. In particular, the physical capacity of the Welland Canal is being reassessed. A summary of the workshops and copies of submitted statements will be made available to the International Joint Commission.

The Board appreciates the suggestions made to improve future workshops. These will be passed on to the Commission and other Boards for their consideration when planning workshops and public meetings. We have tried to answer all requests for further information received at the workshops or through correspondence. If we have missed you, let us know!

Address correspondence to:

International Great Lakes Diversions and Consumptive Uses Study Board
c/o Public Affairs Office
U.S. Army Corps of Engineers
Box 1027
Detroit, Michigan 48321
Telephone: (313) 226-4680 Detroit

or

c/o Department of Environment
Inland Waters Directorate
Water Planning and Management Branch
Ottawa, Ontario K1A 0E7
Telephone: (819) 997-1781 Ottawa

Diversions

INTERNATIONAL GREAT LAKES DIVERSIONS
AND CONSUMPTIVE USES STUDY

-DRAFT-

No. 5 Nov. 1981

A Summary of Man's Impact on Great Lakes Water Resources

On Feb. 21, 1977, the International Joint Commission started to investigate the factors that have or may have an effect on the water levels and flows in the Great Lakes basin. The Commission was acting on a joint request from the Canadian and United States governments to look into the following matters:

- Existing and reasonably foreseeable patterns of consumptive uses of Great Lakes waters:
- Existing diversions, including the Welland Canal and the New York State Barge Canal, and federally, state or provincially sponsored or approved proposed new or changed diversions, within, into or out of the basin; and, in particular.
- Existing diversions at Chicago and at Long Lac/Ogoki, and the proposed study and demonstration program authorized by United States P.L. 94-587 affecting the rate of diversions at Chicago.

In response, the Commission established the International Great Lakes Diversions and Consumptive Uses Study Board on May 3, 1977, issued a directive to it concerning the conduct of the study, and subsequently instructed it to consider the possibilities of diversion management to alleviate extreme lake levels. The Board, in turn, established a working committee and three subcommittees on 1) diversions, 2) consumptive uses, and 3) environmental evaluation.

To prevent a duplication of effort, the Diversions and Consumptive Uses Study Board made use of data generated by the ongoing International Lake Erie Regulation Study Board. This cooperation maximized the use of available professional resources.

In 1980, the board conducted public workshops at selected cities in the Great Lakes basin. These workshops provided opportunities to inform the public and, through open discussion, to answer questions and elicit views concerning study techniques and emerging results. These public views have been incorporated into the Board's work.

This issue of Diversions is the fifth and final in a series of newsletters published by the Board during the course of the study.

Study Results

The study **findings** are as follows;

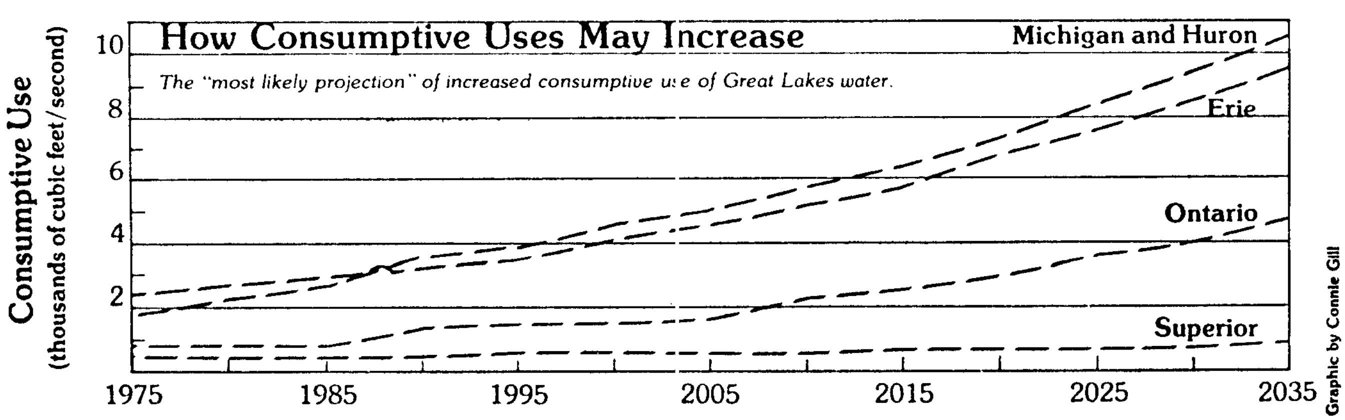
a) The existing diversions have produced changes in Great Lakes levels and outflows;

b) Diversion rates could be modified without structural change at existing diversion locations;

c) By management of the diversions, it is possible to impact on the Great Lakes outflows and extreme high lake levels, but such management would result in a net economic loss and some unquantifiable environmental impacts;

d) Any alterations in diversion rates to raise the extreme low lake levels and outflows would be infeasible;

e) The existing diversion of water through the New York State Barge Canal has no material impact on Great Lakes levels, nor would any modifications thereof;



Study Results...(cont.)

f) Diversion of water into Lake Superior from Long Lac/Ogoki has averaged 5,600 cfs (cubic feet per second) since its inception;

g) The Welland Canal Diversion has varied over time and averaged approximately 9,200 cfs in 1980;

h) The Lake Michigan Diversion at Chicago has varied over time and since 1970 has averaged 3,200 cfs;

i) There are no known significant new or changed diversions proposed for the Great Lakes;

j) Consumptive uses of water are projected to increase from the 1975 rate of 4,900 cfs to an amount which could range from approximately 16,000 cfs to 37,000 cfs by the year 2035;

k) The consumptive uses of water reduce the net water supply to the lakes, thereby lowering lake levels, resulting in economic benefits to coastal zone interests and losses to navigation and power interests; and,

l) Consumptive uses in the future will limit the ability of the current operational regulation plan for Lake Ontario to satisfy the criteria contained in the Commission's Orders of Approval.

The Board's **conclusions** are that:

a) The diversion rates into, within and out of the basin cannot be altered to reduce extreme high levels on the Great Lakes without causing an overall long-term net economic loss;

b) The diversion rates into, within and out of the basin cannot feasibly be altered to increase extreme low levels on the Great Lakes during periods of low supply;

c) Periodically, all diversions (regardless of size) should be monitored and their accumulated effects estimated, evaluated and reported upon so that appropriate public policies can be developed; and,

d) Consumptive uses should be periodically monitored and their impacts, along with various control strategies, studied so that appropriate public policies can be developed to minimize long-term adverse effects.

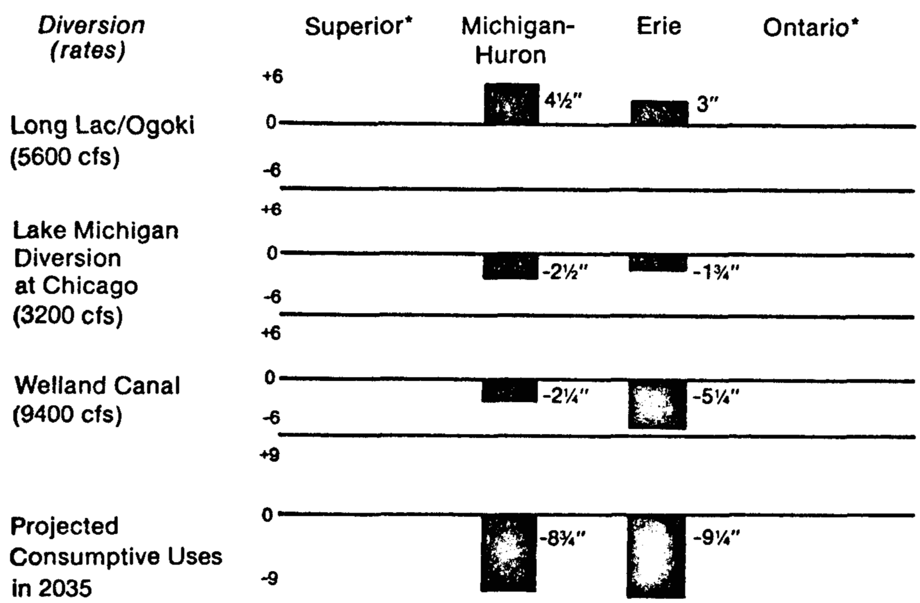
Based upon the above finds and conclusions, the Board **recommends** that:

a) No further consideration be given to the concept of managing Great Lakes levels and outflows through the manipulation of the existing diversions; and,

b) The International Joint Commission, in light of conclusions (c) and (d) above, recommends to governments that a mechanism be established for institutional consultation so that monitoring can be undertaken and appropriate public policies can be formulated to address the potential future impacts of new or increased diversions and consumptive uses.

The final report will be sent to the International Joint Commission by the end of 1981. The Commission will, in due course, furnish the document to concerned government agencies for comment. In addition, it generally holds public hearings on Board reports. Based upon the responses received, the Commission prepares its report with recommendations to the governments.

Approximate Effect of Existing Diversion Rates and Future Consumptive Uses on Mean Great Lakes Water Levels (To nearest ¼ inch)



*Regulation plans for these lakes have been designed to accommodate the diversions and presumably would be modified to accommodate increasing consumptive uses.

The effects of the existing diversions, at the rates indicated, on mean Great Lakes water levels are shown on the above diagram. The diagram shows that the Long Lac/Ogoki Diversions increase the levels of the lakes while the Lake Michigan Diversion at Chicago and the Welland Canal Diversion, and the projected consumptive uses, reduce the levels. The net effect of these diversions is small in comparison to the effect of natural factors(precipitation, evaporation, run-off, etc.) on the fluctuation of Great Lakes levels of 3.8 feet on Lake Superior, 5.7 feet on Lakes Michigan-Huron, 6.9 feet on Lake Erie and 6.6 feet on Lake Ontario. Although the current diversion rate of the Welland Canal is 9200 cfs, the Study Board has evaluated a rate of 9400 cfs, which could occur in the near future due to increased vessel traffic.

INTERNATIONAL GREAT LAKES DIVERSIONS AND CONSUMPTIVE USES STUDY BOARD

Report on Public Workshops

1. Attendance

1.1 Out of a total distribution of 4,000 questionnaires, 374 (9.3%) returns were received. Two hundred and twenty-eight (61%) of the respondents indicated that they would attend a workshop. The remainder could not attend for various reasons, mainly distance from workshop locations or earlier commitments.

1.2 In fact, 117 (51%) people actually attended the workshops. Distribution was as follows:

		No. of Participants	
		Expected	Actual
May 14, 1980	Sault Ste. Marie, Ontario	17	7
May 15, 1980	Chicago, Illinois	32	14
May 20, 1980	Buffalo, New York	40	22
May 21, 1980	Toronto, Ontario	16	10
May 22, 1980	Detroit, Michigan	123	64
		228	117

1.3 Based on an analysis of the evaluation sheets, the participants' major areas of interest were: shore property and recreation, followed by fish and wildlife; a smaller percentage were interested in consumptive use, hydroelectric power and navigation. An examination of the questionnaires returned by those who expressed an interest but could not attend, indicated that their interests paralleled those of the actual participants.

1.4 Fourteen statements were received from the public at the workshops. Available copies are on the Working Committee's file. The essence of these statements will be included in the Board's final report to the International Joint Commission. Copies will be appended as appropriate.

2. Timing

2.1 In accordance with public preferences as expressed in the mail back questionnaire, workshops were held in the afternoon at all locations except Buffalo. An evening workshop was held in Buffalo so as not to conflict with the Great Lakes Basin Commission afternoon meeting on May 20. The high response from the Detroit area warranted the scheduling of an additional workshop in the evening.

2.2 Two weeks prior to the workshops, a flyer was mailed out to remind potential attendees and to give details on workshop times and locations.

3. Workshop Format

3.1 The Working Committee co-chairmen served as workshop moderators in their respective countries. After the introduction of workshop principals, a half-hour slide-illustrated presentation was made on study progress and preliminary findings. This included the main diversion management scenarios and their hydrologic and environmental implications, projected trends on consumptive use and assocated hydrologic effects, and an outline of the methodology being used by the Board to evaluate selected diversion management scenarios.

After the presentation, statements were accepted from the public; this phase was followed by a general discussion period.

4. Main Topics of Discussion at Workshops

The following is a summary of statements received and of the questions that tended to recur throughout the workshops.

4.1 A total of fourteen statements were by the public, 10 of them at Detroit.

At Buffalo: Erie County Shoreline Task Force

At Detroit: Michigan Shorelands Preservation Association - Dudley Taber

League of Women Voters - Verona Morse

Wayne County Conservation Association - Wayne Schmidt

Macomb County Board of Commissioners

Lake Erie Advisory Committee - Richard Micka

Inter-Lake Yachting Association - Lary Leibold

Grandview Beach Association - Mr. Yaryon

Shore Property Owners Association - Franklin Davis

The remainder were given by unaffiliated individuals.

4.1.1 Main points made in the statements were as follows:

- adverse impacts of high water levels were outlined
  - land use restricted
  - flooding and erosion
  - increased construction and maintenance costs due to high water table
  - increased risk of pollution of domestic water supplies due to higher water table.

- suggested levels for regulation - return to datum level; pre 1970's levels; Lake St. Clair - 574.1 max. and 572.1 min. and Lake Erie 571.0 max. and 569.2 min.

- suggested means to bring levels down - shut off Long Lake-Ogoki, greater flow at Chicago and Welland, open locks at Black Rock Ship Canal and build the Squaw Island Diversion.

- suggested the Board should consider the plight of the shore property owner rather than navigation and power interests. The general perception was that lake levels were maintained for the benefit of those two interests.

- called for energy conservation; consideration of alternate sources of power and ways in which navigation losses could be compensated, i.e., surtax on transported goods.

- all favoured scenario 4: Long Lake Ogoki - 0; Chicago - 8700 cfs; Welland - 9000 cfs.

4.2 Recurring and/or Significant Questions and Observations

4.2.1 Chicago Diversion

- do the diversion rates include consumptive use

- diversion of 8700 cfs - how was this rate established; how much water could be diverted at Chicago

- what was the economic impact on Chicago of lower lake levels due consumptive use.

4.2.2. Long Lake-Ogoki

- great deal of interest was shown in the history of the diversion

- confusion about how it operates - the natural flow of 16,000 cfs and diversion of 5,400 at Long Lake

- amount of power lost when the diversion is shut down

- most people saw this diversion as being partly responsible for higher levels at present; general support for shutting it down, however, most American participants were aware that Canada was not likely to support such an action.

4.2.3 - Consumptive Use

- projected increases in consumptive uses surprised people - wanted to know what conservation assumption had been made

At Canadian workshops - interest was expressed in the increasingly disproportionate withdrawals made by Canada and the U.S. - what were the implications for future power sharing?

4.2.4 Evaluation Methodology

- how the figures for erosion damage reduction per 1 ft of lowering per mile were derived

- how the orders of magnitude of benefits and losses for the main interests were calculated

- how would the main interests be weighed in the final analysis

- the environmental impact of lower levels, due to consumptive uses, on fisheries and wetlands. Also concern was expressed about the impact of decreased range of fluctuations on fish reproduction, under the diversion management scenarios.

4.2.5 Impact of landfills on water levels - this topic was discussed both at Detroit and Chicago. It was alleged that landfills in the Niagara River has raised Lake Erie by 1".

4.2.6 Dredging

- this was seen as a way of satisfying both navigation and shore property interests. Suggestions to dredge Lake St. Clair and the Detroit River were made.

4.2.7 High Water Proponents

(a) Cleveland Yacht Clubs - high levels curtail the need for expensive dredging

(b) Milwaukee - downtown core is built on wood pilings - high levels keep pilings wet and preserve them.

5. Evaluation

5.1 The evaluation sheets indicated that a majority of participants gave high marks to the workshops as a vehicle for information exchange. They were satisfied both with the information presented and with opportunity to express their views and an overwhelming majority said they were pleased with the responses to their questions.

5.2 Suggestions to improve the presentation and discussions included the following:

- do not assume participants have a good technical grasp of the subject
- representation from other interests i.e., navigation and power
- better charts and graphs and more time to absorb the information
- more information prior to the workshops
- more workshops so people would not have to travel so far.

5.3 Other Comments

- what is needed above all is an estimate of the relative cost to the public of lowering the levels in dollars and cents, e.g., increased cost of shipped goods, power, etc., as opposed to shore property damage due to high levels.

- evaluation of shipping and power losses versus shoreline losses is out of balance. The former can be classified as minor since they are replaceable or recoverable but shoreline losses are forever.

- excellent workshop but the negative aspects is that it will be many years before regulation of Lake Erie is accomplished.

6. Conclusions based on Public Input Received at Workshops

a. Reduction of lake levels, even by a few inches, is viewed as critical by riparian interests.

b. Based on the response at workshops, American riparian interests seem to be more concerned than Canadian riparian interests. Reduction of lake levels may not receive much popular support on the Canadian side, particularly if the trade off is more expensive power and transportation of goods.

c. Shore property interests feel that the lakes are being regulated for navigation and power interests at their expense. They will look to the Board's report for clarification as to whose interests get priority. The argument that lake level reduction will result in a net economic loss to the system will not receive support from the riparian interests. They feel they have indirectly subsidized navigation and power during the high water period thus far and it is time for them to receive some consideration. For example, the Board was asked to bear in mind that shipping and power losses are receoverable or replaceable whereas shoreline losses are forever. This sort of "Environment versus Dollars" argument is also supported by the "environmental community."

d. The "environmental community" participating at the workshops was not large but well informed. They were critical of the lack of data presented on environmental impacts, particularly those impacts that may be associated with levels reduced by consumptive uses.

e. The workshops increased public awareness of the hydrological impacts of consumptive use. Interest was expressed in what economic impacts would be associated with such reductions. Further questions on the consumptive uses portion of the Study can be expected when the Board's Report is released, particularly with regard to conservation assumptions made in projects and associated environmental and economic impacts.

7. Implications of the Workshops for the Study

a. The workshops reinforced the validity of the Board's perception of riparian interests as reflected in the Plan of Study, therefore, the overall study direction has not changed. The Board has made, and continues to make, adjustments in response to both perceived and expressed public concerns. For example, the physical capacities of the Welland and Long Lake-Ogoki diversions were re-examined as were the consumptive use projections and associated hydrological impacts.

b. The workshops resulted in improved public relations with riparian interests. The public obtained a better understanding of the Great Lakes system and of the constraints and difficulties faced by the Study Board. This will likely result in greater public confidence in study findings.

An added spin off is that the Corps of Engineers reputation seems to have been enhanced by the U.S. workshops.

ANNEX D

Prior reports that were pertinent or of special interest to this study.

a. A report dated December 30, 1911, on Regulation of Lake Superior by Noble and Woodard, consulting engineers for the Michigan-Lake Superior Power Company, devised a rule for such regulation. The study envisaged a control structure differing from that finally constructed and the regulation plan was superceded upon completion of the structure. It is perhaps interesting to note that the tabulation of Lake Superior "supply factors" presented in the report continues to be used today and is extended monthly.

b. A report on Diversion of Water from the Great Lakes and Niagara River, frequently referred to as the Warren Report, was transmitted to the Speaker of the House of Representatives, Congress of the United States on December 7, 1920. In a discussion of lake regulation as a means of restoring navigation depths on the lakes, reference is made to an earlier report by the Deep Waterways Board, dated June 30, 1900, which at that early date presented a plan for the regulation of Lake Erie.

c. In 1926, John R. Freeman completed for the Chicago Sanitary District a report on Regulation of the Great Lakes and Effect of Diversions by Chicago Sanitary District. Among other things, the report suggests the possibility of lake regulation, which would raise both the high and low lake levels by appreciable amounts.

d. In July 1963, the International St. Lawrence River Board of Control submitted a report to the IJC entitled Regulation of Lake Ontario - Plan 1958-D. The report describes in detail the plan of regulation which has been in effect from October 1963 to present.

e. In December 1965, the United States Army Corps of Engineers issued a report entitled Water Levels of the Great Lakes, Report on Lake Regulation. The report presents study plans developed by the Corps and summarizes other pertinent information and data in a form to be useful to an international study on the subject. The Corps' report provides a considerable discussion of the physical and economic aspects of the lakes, a knowledge of which is necessary for definition of present day problems.

f. In December 1973 the International Great Lakes Levels Board submitted a report on Regulation of Great Lakes Water Levels to the International Joint Commission. The report deals with the further regulation of the Great Lakes based upon available supplies of water within the Great Lakes basin. It presents the hydrology and hydraulics of the Great Lakes system and analyzes the economic and environmental impacts of fluctuation in the lake levels and outflows.

g. In 1976 the International Joint Commission submitted a report entitled Further Regulation of the Great Lakes to the governments of Canada and the United States. The report is based upon the above noted 1973 report on regulation of the Great Lakes water levels.

h. In 1976 the Great Lakes Basin Commission issued a report entitled Great Lakes Basin Framework Study. The report consists of a main report, 23 Appendices and an Environmental Impact Statement. The report provides a good information base for studies on the U.S. sector of the basin.

i. Regulation of Lake Superior (Plan 1977) - The report describes in detail the current operating plan of regulation for the lake. The report consists of a main report and an Environmental Impact Statement.

ANNEX E

State, Provincial, and Federal Agencies that participated in the International Great Lakes Diversions and Consumptive Uses Study, including individual participation and their period of involvement.

UNITED STATES

Corps of Engineers

North Central Division

Brigadier General Scott B. Smith,
Chairman, Study Board (12/80 - *)

Major General Richard L. Harris,
Chairman, Study Board (7/78 - 12/80)

Colonel Andrew C. Remsen, Jr.,
Chairman, Study Board (2/78 - 7/78)

Brigadier General Robert L. Moore,
Chairman, Study Board (6/77 - 2/78)

Mr. Zane Goodwin,
Alternate Member, Study Board (9/80 - *)

Mr. Donald J. Leonard,
Secretary, Study Board (6/77 - *)

Detroit District

Colonel Robert V. Vermillion,
Chairman, Working Committee (8/79 - *)

Colonel Melvyn D. Remus,
Chairman, Working Committee (8/77 - 8/79)

CANADIAN

Federal Department of the Environment

Mr. Ralph L. Pentland,
Chairman, Study Board (9/78 - *)

Mr. Norton H. James,
Chairman, Study Board (6/77 - 9/78)

Mr. D.A. Gerald MacMillan,
Secretary, Study Board (6/77 - *)

Mr. John Bathurst,
Chairman, Working Committee (6/77 - *)

Mr. Raimo Kallio,
Secretary, Working Committee
Member, Public Involvement Ad-Hoc
Group (2/80 - *)

Mr. Robert Condie,
Secretary, Working Committee
Member, Public Involvement Ad-Hoc
Group (6/77 - 6/80)

Mrs. Dana Vindasius,
Member, Public Involvement Ad-Hoc
Group (3/78 - *)

Mr. David F. Witherspoon,
Chairman, Diversions Subcommittee
(6/77 - *)

*Present

UNITED STATES

Mr. Benjamin G. DeCooke,
Alternate Chairman, Working Committee
Chairman, Diversions Subcommittee
(6/77 - *)

Mr. Philip Gersten,
Secretary, Working Committee
Associate, Diversions Subcommittee
Member, Public Involvement Ad-Hoc Group
(1/78 - *)

Mr. Darryl Dolanski,
Secretary, Working Committee
(6/77 - 1/78)

Mr. John R. Collis,
Chairman, Environmental Evaluation
Subcommittee (6/77 - *)

Mr. Michael Perrini,
Member, Public Involvement Ad-Hoc Group
(9/78 - *)

Mr. Gordon Larson,
Associate, Diversions Subcommittee
(5/78 - *)

Ms. Nanette Tack,
Associate, Diversions Subcommittee
(10/80 - *)

Dr. James E. Galloway,
Associate, Environmental Evaluation
Subcommittee (9/77 - 2/81)

Ms. Florence Kuznia,
Associate, Environmental Evaluation
Subcommittee (9/79 - 1/80)

CANADIAN

Mr. Jim Robinson,
Associate, Diversions Subcommittee
(6/77 - *)

Mr. Douglas I. Gillespie,
Chairman, Environmental Evaluation
Subcommittee (6/77 - 2/80)

Dr. Al R. LeFeuvre,
Liaison, Lake Erie Regulation Study
Board (11/77 - *)

Mr. Peter P. Yee,
Liaison, Lake Erie Regulation Study
Board (7/77 - *)

Mr. Ray Beauchemin,
Liaison, Lake Erie Regulation Study
Board (8/78 - 7/79)

Mr. N. P. Persoage,
Liaison, Lake Erie Regulation Study
Board (7/77 - 8/78)

Mr. Donald Tate,
Associate, Consumptive Uses Subcommittee
(3/78 - 2/80)

Mr. J. J. Brown,
Technical Advisor (1/78 - 7/80)

Federal Department of Transport

Mr. Ralph H. Smith,
Member, Study Board (6/77 - *)

Mr. G. Reginald Golding,
Member, Working Committee (6/77 - *)

*Present

UNITED STATES

Mr. Brooks Williamson,
Associate, Environmental Evaluation Subcommittee (6/78 - 8/79)

Ms. Marylin Jones,
Member, Public Involvement Ad-Hoc Group (11/79 - 6/81)

Ms. Amber Weipert,
Member, Public Involvement Ad-Hoc Group (4/78 - 11/79)

Buffalo District

William Erdle,
Liaison, Lake Erie Regulation Study, (6/77 - *)

Chicago District

Mr. Paul Mohrhardt,
Technical Advisor (9/78 - *)

State of Michigan

Department of Natural Resources

Mr. William D. Marks,
Member, Study Board (6/77 - *)

Mr. Mogens Nielson,
Member, Working Committee (9/78 - *)

Mr. Fredrick Clinton,
Member, Working Committee (6/77 - 9/78)

CANADIAN

Ontario Ministry of the Environment

Mr. Donald N. Jeffs,
Member, Study Board (8/80 - *)

Mr. Grant H. Mills,
Member, Study Board (6/77 - 8/80)

Mr. Ronald C. Hore,
Member, Working Committee
Chairman, Consumptive Uses Subcommittee (6/77 - *)

Mr. Douglas Vallery,
Associate, Consumptive Uses Subcommittee (6/77 - *)

Quebec Department of Natural Resources

Mr. Bertrand Bouchard,
Member, Study Board (6/79 - *)

Ontario Hydro

Mr. Roy A. Walker,
Member, Study Board (6/77 - *)

Mr. John M. Spratt,
Member, Working Committee (6/77 - *)

Ontario Ministry of Natural Resources

Mr. Tom M. Kurtz,
Member, Working Committee (1/78 - *)

*Present

UNITED STATES

CANADIAN

State of Illinois

Division of Water Resources

Dr. Frank L. Kudrna, Jr.,
Member, Study Board (8/78 - *)

Mr. Peter L. Wise,
Member, Study Board (6/77 - 8/78)

Mr. Daniel Injerd,
Member, Working Committee (9/80 - *)

Mr. Kenneth L. Brewster,
Member, Working Committee (6/77 - 9/80)

State of Pennsylvania

Department of Environmental Resources

Mr. R. Timothy Weston,
Member, Study Board (10/80 - *)

Mr. Clifford H. McConnell,
Member, Study Board (6/77 - 6/80)

Mr. Stephen Runkle,
Member, Working Committee (2/80 - *)

Mr. William N. Frazier,
Member, Working Committee (7/77 - 2/80)

Federal Energy Regulatory Commission

Mr. James D. Hebson,
Member, Study Board (6/77 - *)

Mr. Martin Inwald,
Member, Working Committee (7/77 - *)

*Present

UNITED STATES	CANADIAN
Chicago, Illinois Department of Water and Sewers	
Mr. John B. W. Corey, Member, Working Committee (9/77 - *)	
Environmental Protection Agency	
Mr. Chris P. Potos, Technical Advisor (8/78 - *)	
Mr. Joseph Tynsky, Technical Advisor (1/78 - 8/78)	
National Oceanic and Atmospheric Administration	
Dr. Arthur Pinsak, Chairman, Consumptive Uses Subcommittee (9/78 - *)	
Mr. C. Fredrick Jenkins, Chairman, Consumptive Uses Subcommittee (6/77 - 9/78), (7/79 - 5/80)	
Ms. Heather D. Wicke, Associate, Consumptive Uses Subcommittee (9/77 - 3/80)	
Great Lakes Basin Commission	
Mr. Charles Job, Observer (4/78 - *)	

*Present

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